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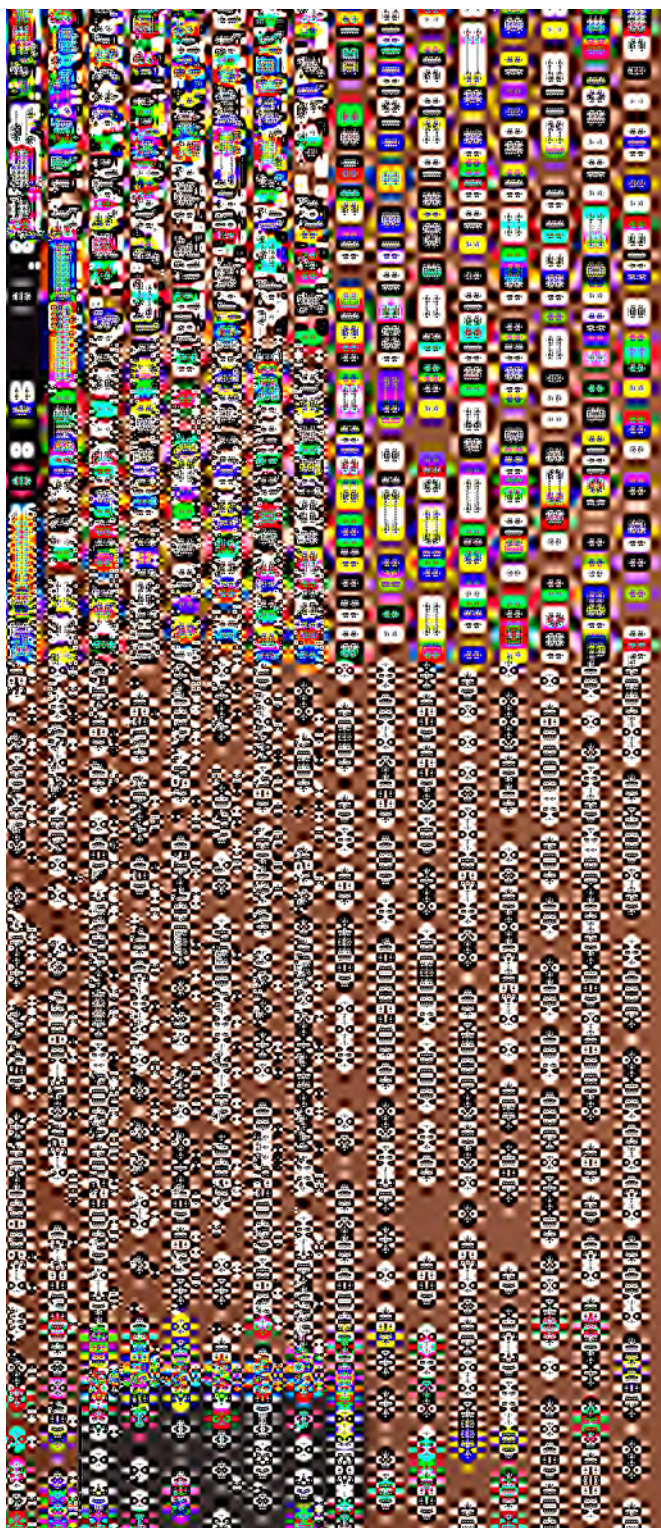
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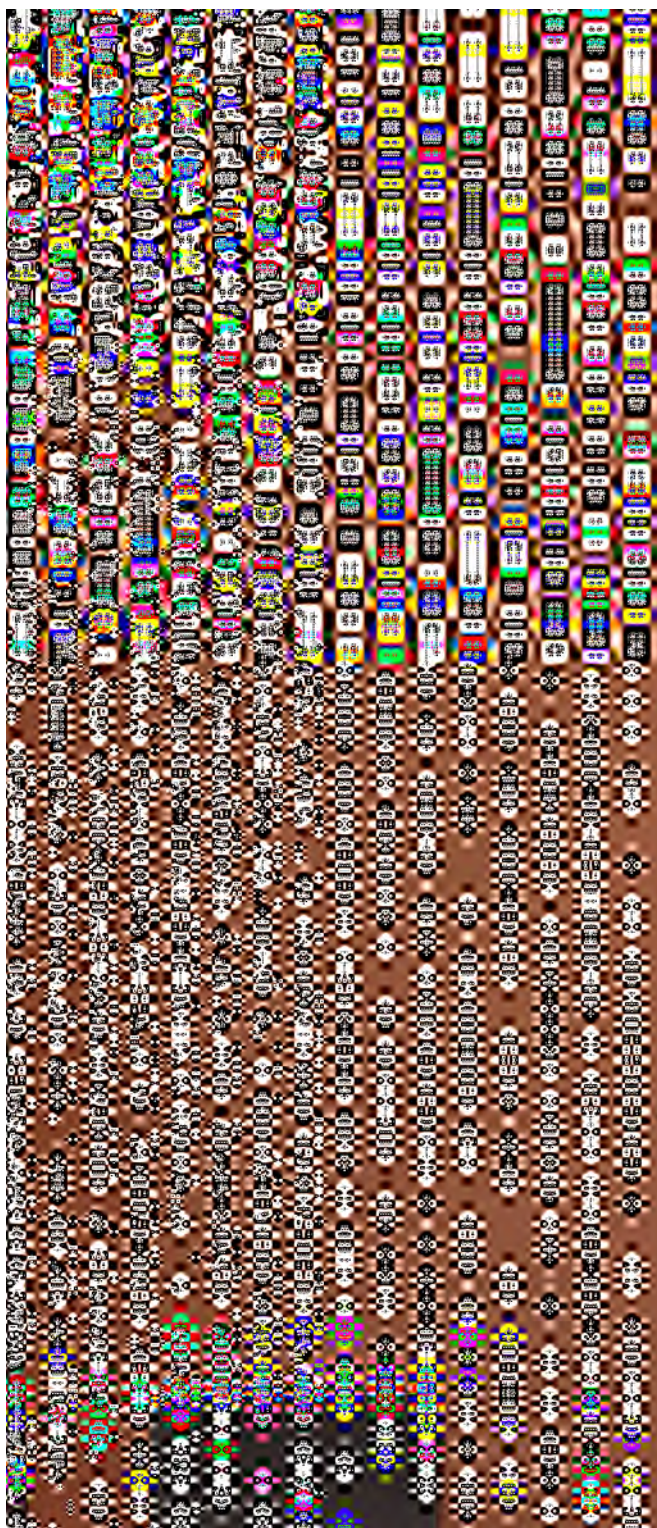
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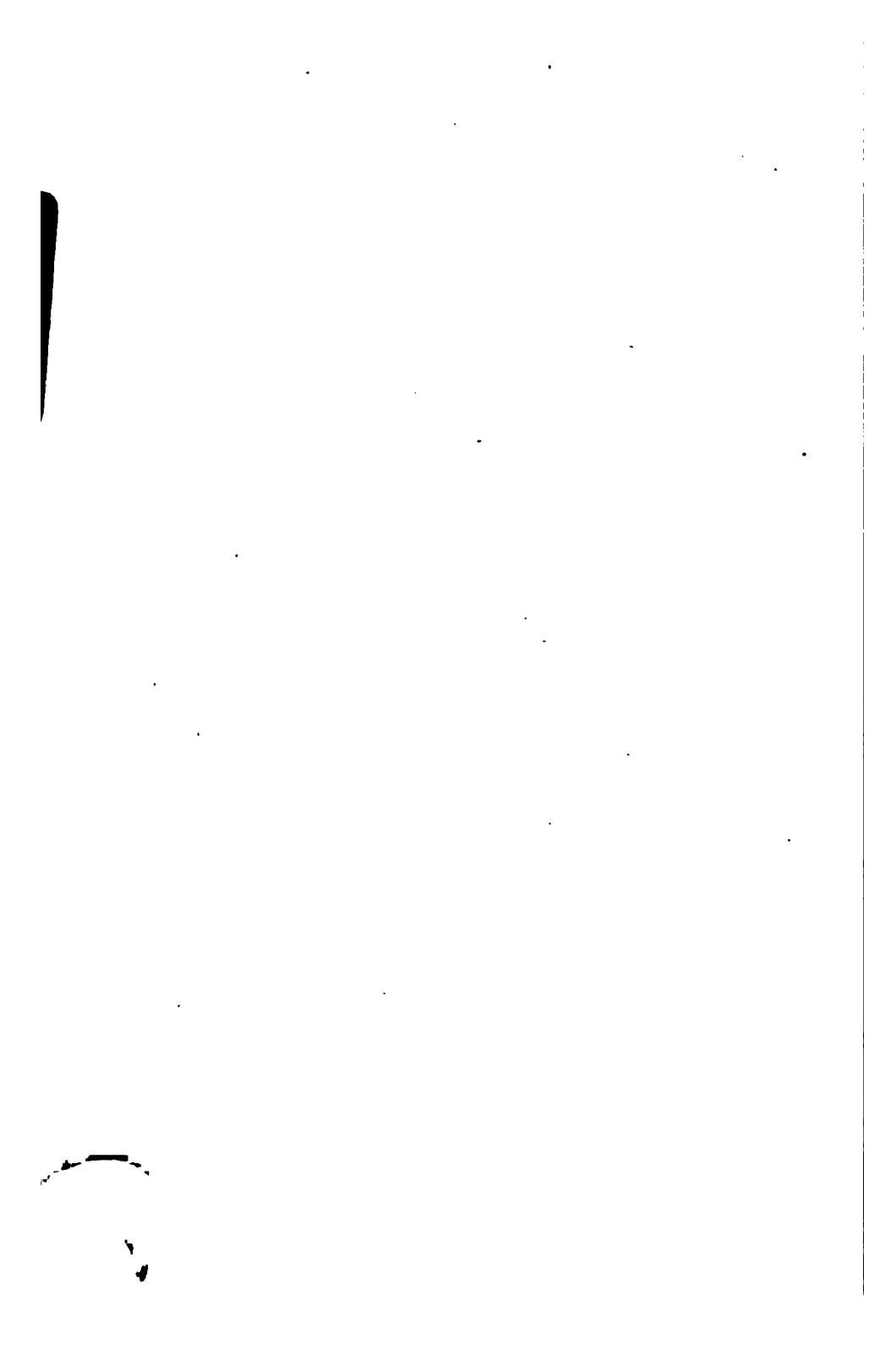




















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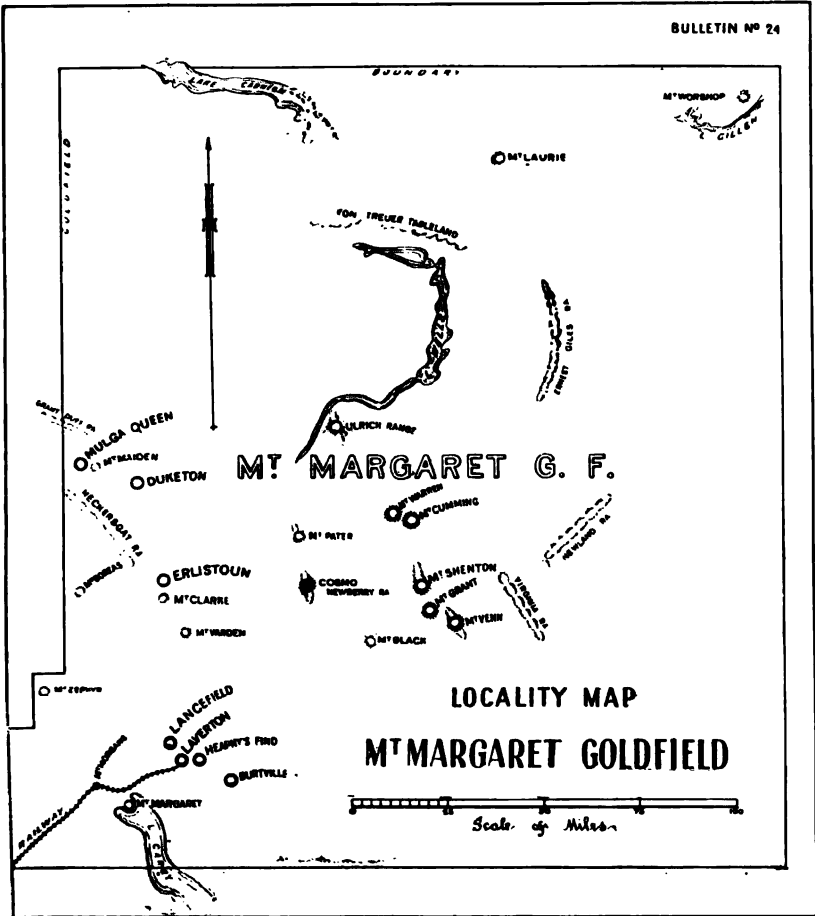
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## PREFATORY NOTE.

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**T**HIS Report makes another of the special series dealing with the different mineral fields of the State.

The report and accompanying maps represent the results of Mr. C. G. Gibson's investigations in a portion of the Mount Margaret Goldfield, and include descriptions of the mining centres of Laverton, Burtville, the Erlistoun district, together with an account of the Cosmo Newberry Ranges, Mounts Shenton, Venn, Warren, and Cumming, and the Ulrich Range.

The field work upon which Mr. Gibson's observations are based, was commenced on the 15th of May and completed on the 26th of November, 1905.

In addition to this officer's own work, Mr. Gibson's report includes a brief *aperçu* of the labours of the other official observers in the district, and is accompanied by a series of geological and mining plans, which make the descriptive portions of the report intelligible.

The rocks of the district comprise a complex of crystalline rocks, identical with that which forms the auriferous series in other portions of the State, and therefore need no further reference in this place.

A. GIBB MAITLAND,  
Government Geologist.

Geological Survey Office,  
Perth, 27th July, 1906.



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# Laverton, Burtville, and Erlistoun Auriferous Belt,

## MT. MARGARET GOLDFIELD.

### Boundaries of the Field.

The Mount Margaret Goldfield, which was previously included in the North Coolgardie Field, was declared, by proclamation, gazetted on the 12th March, 1897, to take effect from the 1st April of that year; its boundaries were amended by a further proclamation, gazetted on 28th March, 1902, taking effect on the 2nd April, 1902, so as to embrace an area of 42,252 square miles.

The boundaries, as defined by the authorities, are as follows:—

"Bounded by lines starting from a point about fifteen miles East, and about thirteen miles North from the summit of Mount Ida, and extending North about thirty-five and a-half miles; thence East about sixty-seven and a quarter miles, passing through a tree marked A.N. 33, at Doyle's Well; thence North about fourteen miles; thence East about seven miles; thence North to the 26th parallel of South latitude; thence East to the 125th meridian, East longitude; thence South to a spot due East of a tree marked B. 82, at Brickey's Soak; thence West through the said tree to the starting point. Excluding all townsites and fee simple lands within the boundaries."

*Mining Centres examined and mapped.*—The centres examined and reported on were Laverton (including Lancefield and Ida H.), Burtville, Erlistoun, Duketon, Mulga Queen, and the country at the Cosmo Newberry Ranges, and in the vicinity of Mounts Shenton, Venn, and Warren, as well as the reported new find situated in the Ulrich Ranges, 60 miles north-east of Duketon. Of Laverton, Lancefield, Ida H. (Heaphy's Find), and Burtville, geological sketch maps have been prepared on a scale of 20 chains to one inch; while of Erlistoun, Duketon, and Mulga Queen, black and white maps have been made showing the positions of the principal lines of reef.

*Early History of the Mount Margaret Goldfield.*—The earliest mention of the Mount Margaret district is found in the journal of Sir John Forrest, when he was in command of the West Australian Expedition in search of the remains of Dr. Leichardt and party in 1869, and the history of the district may, therefore, be said to start with the following extracts from his diary of the expedition:—

- "June 20th, 1869 . . . . . Saw a high hill bearing N. 81° 30' E., mag. and about twenty-five miles distant, which I named Mount Leonora, and another bearing N. 67° E., mag. about twenty-five miles distant which I named Mount George. Intend proceeding to Mount Leonora to-morrow . . . . .
- "June 21st. Steering towards Mount Leonora over some tolerably grassy country, we reached it at sundown and camped . . . . . in South latitude 28° 53' by meridian altitudes of Lyræ (Vega) and Aguilæ (Altair) and in longitude about 121° 21' East

- " June 23rd . . . . . Passing Mount Leonora we steered N. 81°  
 " 15° E. mag. to a table hill, which . . . . . I called it Mount  
 " Malcolm . . . . . Saw a remarkable peak bearing N.  
 " 65° E. mag. distant about 20 miles . . . . . which I named  
 " Mount Flora . . . . . and from which I obtained a round  
 " of bearings. Saw a high range bearing about N. 106° 15' E. mag.  
 " apparently about sixteen miles distant, towards which we travelled  
 " till after dark . . . . .
- " June 24th. Saddled at dawn and proceeded to the range, which bore N.  
 " 93° 30' E. mag. about five miles distant, on reaching which I ascended  
 " the highest point and named it Mount Margaret . . . . . From  
 " the summit of Mount Margaret the view was very extensive. There  
 " was a large dry salt lake to the southward as far as the eye could reach,  
 " while to the East and North-East there were low trap ranges lightly  
 " grassed. A high table hill bore N. 73° E. mag. . . . .
- " July 1st . . . . . Reached the table hill, which I ascended, and  
 " took a round of angles. I have since named this hill Mount Weld,  
 " being the farthest hill seen eastward by us."

From that date but little further knowledge was gained of the country, or, indeed, little attention was paid to it for more than twenty years; and it was not until 1894 that the Mount Margaret, or Lake Carey, country began to be regarded as a rising and prosperous district.

At the end of 1895, the population of the whole of the district amounted only to 730; there were 3,400 acres held under mineral lease, and two ten-stamp batteries were erected at Mount Margaret.

During 1896 numerous new finds were reported, principally at Mount Margaret, Mount Malcolm, Mount Leonora, and Murrin Murrin, whilst an important discovery of copper was made six miles to the east of Princess Alex. (Murrin Murrin); townships also sprang up at these places.

It was not until 1st April, 1897, that the Mount Margaret was constituted an independent goldfield, formed by separating portions of the North Coolgardie and East Murchison Goldfields. It had at this time an area of 19,166 square miles, and was divided into the districts of Mount Margaret, comprising an area of 17,150 square miles, and Mount Malcolm, with an area of 2,516 square miles.

Apparently at the time, the centre of Mount Malcolm gave promise of being the most important, and the Warden's office for the transaction of the departmental business of the new field was opened there on the 10th May, 1897. On the 24th December, in the same year, the area of the Mount Margaret district was increased to 39,638 square miles, by the inclusion of a portion of the East Murchison Goldfield.

In this year, the Westralia Mount Morgans Gold Mines was registered as a local company, and on 3rd March following the Sons of Gwalia, Ltd., which gave great impetus to the mining centres of Leonora and Morgans, these two mines being the chief producers of the field. The Under Secretary for Mines in his Annual Report for 1898, refers to the developments of the field during that period as being little short of phenomenal.

The population at the end of 1898 was 1,725.

In 1899 the boundaries of the districts were further amended, so that the Mount Margaret district comprised an area of 39,510 square miles, and the whole field an area of 42,154 square miles. During this year, a public battery started operations at Leonora, and further copper deposits were found and furnaces erected at Anaconda, in the vicinity of Murrin Murrin, where similar ores has been previously located. The yield of gold for the year amounted to 5 per cent. of the total production of the State. Developments were almost equally satisfactory in the following year (1900), especially in the vicinity of Mount Margaret, and to the east and south-east of Laverton, and 4,539 tons of copper ore were treated at Anaconda. The gold yield rose from 5 per cent. to 9.6 per cent. of the State's total production, a proportion which increased to 10.3 per cent. in 1901, when the copper output from Murrin, valued at £40,738, amounted to rather more than half the State's total. The Warden of the field reported at the end of 1901, that progress was marked more by attention to legitimate development of prospecting shows and mining at a depth than by the opening up of new country; remarks which also apply to the following year when, however, the yield of copper showed a falling off, the output being only valued at £6,852. During this year (1901) a State battery was started at Leonora.

During 1902 the gold production maintained its satisfactory increase. Two new townsites were declared at Burtville and Euro, and a State battery was erected at Laverton. A slight alteration was made in the administration of the field by the creation of the new district of Mount Morgans, the centres being Malcolm, Morgans, and Laverton, and the area of the field 42,252 square miles; the Warden's head-quarters were removed to Morgans, which thus became the administrative centre. The relative importance of the three centres during this year is shown by the following comparative statement :—

| District.                               | Population. | Production.            |
|-----------------------------------------|-------------|------------------------|
| Mount Malcolm (including Leonora) .. .. | 2,741       | Fine ozs.<br>78,171.96 |
| Mount Morgans .. ..                     | 1,114       | 51,092.42              |
| Mount Margaret .. ..                    | 2,170       | 57,554.60              |

During this year the railway from the coast was opened as far as Leonora.

In 1903, the North Erlistoun district began to attract attention, and the railway was opened from Malcolm to Laverton. The gold production rose to 9.31 per cent. of the State's total.

In 1904, State batteries were erected at Burtville and Duketon, and the gold output rose to 9.59 per cent. of the State's total.

The following table shows the gold returns in fine ounces from the areas covered by the three districts of Mount Morgans, Mount Malcolm, and Mount Margaret up to the end of 1905 :—

|                   | Prior to 1897.  | 1897.            | 1898.            | 1899.            | 1900.             | 1901.             | 1902.             | 1903.             |
|-------------------|-----------------|------------------|------------------|------------------|-------------------|-------------------|-------------------|-------------------|
| Mount Morgans ..  | 294.06          | 3,376.34         | 8,641.76         | 14,652.97        | 31,819.52         | 41,607.09         | 51,092.42         | 59,517.40         |
| Mount Malcolm ..  | 3,887.01        | 15,051.71        | 29,638.28        | 46,399.13        | 77,235.19         | 84,278.40         | 78,171.96         | 83,529.04         |
| Mount Margaret .. | 267.32          | 695.88           | 3,841.20         | 9,202.44         | 17,800.40         | 39,357.52         | 57,554.60         | 39,717.48         |
| <b>Total ..</b>   | <b>4,448.39</b> | <b>19,123.93</b> | <b>42,121.24</b> | <b>70,254.54</b> | <b>126,855.11</b> | <b>165,243.01</b> | <b>186,818.98</b> | <b>182,763.92</b> |

|                   | 1904.             | 1905.             | Total.                  |
|-------------------|-------------------|-------------------|-------------------------|
| Mount Morgans ..  | 45,230.33         | 25,877.33         | Fine ozs.<br>282,109.22 |
| Mount Malcolm ..  | 94,300.27         | 105,897.45        | 618,388.44              |
| Mount Margaret .. | 43,992.65         | 56,937.93         | 269,366.92              |
| <b>Total ..</b>   | <b>183,523.25</b> | <b>188,712.21</b> | <b>1,169,864.56</b>     |



## Previous Observations on the Geology of the Mt. Margaret Goldfield.

In a report on the Interior Gold Region of Western Australia,\* published in 1894, Mr. S. Göczel, describing the country passed over on an expedition from the "Ninety Mile" to Lake Carey, mentions the Lake Raeside depression which he crossed some miles to the south of Mount Leonora, and which forms the drainage area of the southern portion of the field. He noted the position of the large outcrops of granitic rocks which rise as a range of bare hills to a height of 200 feet above the surrounding country, and form, with a width of about five miles, the divide of the water-shed of Lakes Raeside and Carey. Mr. Göczel further stated that a long stretch of country situated at the junction of this gneissic granite on the west and the greenstone on the east had already been proved auriferous, and he mentions the "Red Castle" line of reef, and the "Goose's Puzzle," and stated that though rich finds had not been made up to that time, a number of reefs offered chances for profitable mining enterprise. Farther east, on the range of which Mount Margaret forms the highest point, he referred to alluvial gold deposits at Red Flag, Hawk's Nest, and other surface workings—the Hawk's Nest being the richest.

Since this date no detailed official reports on the district appear to have been made until 1904, when Mr. C. F. V. Jackson, then Assistant Geologist, issued a detailed report on and map of Leonora,† following this up next year with a similar report and map of Mount Morgans. ‡

In the same year, 1904, the State Mining Engineer (Mr. Montgomery) published a short report on the Eristoun and Duketon districts.§ in which he says:—

"The country between these two places (Laverton and Duketon) appears to be favourable throughout for the occurrence of gold, a large number of auriferous reefs having been found at intervals throughout it. It is mostly the usual greenstone of our goldfields, often schistose, while the surface is plentifully strewn with concretionary ironstone, and often with white quartz. Bars of black jasperoid quartz and outcrops of white quartz occur frequently . . . . ."

" . . . . . The Eristoun and Duketon districts are yet in quite the first stage of development, and require a great deal more prospecting and opening before their importance can be justly estimated. Even a flying visit is, however, sufficient to show that the reefs are numerous, and have prospects of gold sufficient to justify high hopes of their future. The impression gained by me was that there was a very valuable district to be exploited."

According to Mr. Jackson's observations, the fundamental rocks of Leonora consist of a complex of crystalline schists, which form the continuation of that group which is so largely developed in other portions of the Eastern Goldfields; these schists comprise both basic

\* Annual Report of the Department of Mines for 1894, Perth: By Authority: 1895.

† Geology and Auriferous Deposits of Leonora, Mt. Margaret Goldfield. Perth: By Authority: 1904.

‡ Geological Features and Auriferous Deposits of Mt. Morgans, Mt. Margaret Goldfield. Perth: By Authority: 1905.

§ Annual Report of the Department of Mines for 1904. Perth: By Authority: 1905.

and acidic rocks. Some of the basic rocks (the greenstones) have been converted into schists which are largely developed along the outer margin of the main belt, whilst the centre portion is occupied by the more or less massive rocks; these schistose and massive rocks are merely portions of one and the same mass which has suffered more or less dynamical metamorphism. All the important ore deposits are confined to the greenstones and their derivatives. The greenstones have been invaded by granitic rocks, which are both massive and foliated, and evidence seems to prove that these are of two distinct ages, (a) an older, traversed by zones of secondary shearing, possibly associated with auriferous quartz reefs, and (b) a much newer and comparatively unmodified granite, which is represented by the felsite dykes, which are found intersecting the greenstones in the vicinity of the Leonora Gold Blocks. Speaking of the Mount Morgans centre, Mr. Jackson remarks that the staple formation consists of a series of basic and acidic rocks of the geological age, of which the district affords no direct evidence, though in all probability it forms part of the same series as that so largely developed in other portions of the Eastern Goldfields, and invariably assumed to be Archæan. The basic rocks, the greenstones, are essentially hornblendic, and have to a considerable extent been converted into schists, these being most prominent along the junction of the greenstones with the granitic rocks. The acidic rocks consists chiefly of quartz and felspar porphyries, and appear to be intrusive into the greenstones; like the latter they have been subjected to considerable local mechanical deformation, and have been converted into what may, for convenience, be best described as granitic schists.

The ore deposits of the Mount Morgans district Mr. Jackson separates into two main divisions,—

- (a.) Lodes which are genetically similar to the banded and hematite-bearing quartz reefs, which form such conspicuous features in the Murchison and Mount Margaret Goldfields; and
- (b.) Gold-bearing quartz reefs of the ordinary type.

The banded quartz lodes form a series of bold outcrops on the summit of the main Mount Morgans ridge, and have been traced across country for about four miles, occurring along the main junction line between the greenstones and the porphyry. They vary much in size, and are very irregular; their chief characteristic is that of a solid body or pipe of lens section, the main axis of which dips to the south at an average angle of about 45 degrees. The ore chutes also have a marked trend to the southward.

The second division, the normal quartz reefs, are found almost entirely within the greenstones to the eastward of the main dividing ridge. It will thus be seen that there is a great similarity in the geological features and mode of occurrence of its ore deposits between this centre and that of Laverton.

## Laverton.

(Including Ida H. and Lancefield.)

(With three Geological Sketch Maps, Plates I., II., and III.)

**Topography.**—The townsite of Laverton, which forms the present terminus of the Eastern Railway, is situated on the eastern side, and near the northern edge of a low, irregular ridge of hills trending in a roughly north and south direction for some four miles or so. Easterly from here, the country consists of level plains extending for about six miles, when another low ridge makes its appearance, also trending north and south through Ida H. and Cock of the North; easterly from here the country consists of alternating low greenstone ridges and loamy plain for many miles. Westward of the main ridge of hills, the country also consists of alternating low ridges on flats for some half-a-dozen miles, when extensive sand plains come in, extending as far as Mount Morgans.

Northerly from the townsite are extensive flats extending for many miles, and broken only by the ridge of hills, of which Mount Crawford forms the highest point, and which extends for only a couple of miles: beyond this again, the plains continue indefinitely.

### General Geology.

Broadly speaking, the formations of Laverton can be divided into two classes, the greenstones and the granites. Of these, the greenstones occupy by far the larger area, and are of by much the greater importance, as it is within them that the extensive H.B. quartz lodes and other auriferous deposits occur. These greenstones are of the types usually found in the West Australian gold-fields, and comprise both massive and foliated varieties as well as occasional small areas of schist, these latter being usually found in close proximity to the granitic rocks. These granitic rocks occupy a comparatively small area, chiefly in the neighbourhood of Mount Crawford, and to the West of the Augusta G.M. They are apparently intrusive into the greenstones. The greater part of the area under examination is covered by a varying thickness of recent detrital deposits, which render accurate mapping almost impossible. There are also a few small areas of laterite throughout the district occurring as the cappings of greenstone hills; they are, however, of small extent and inferior quality.

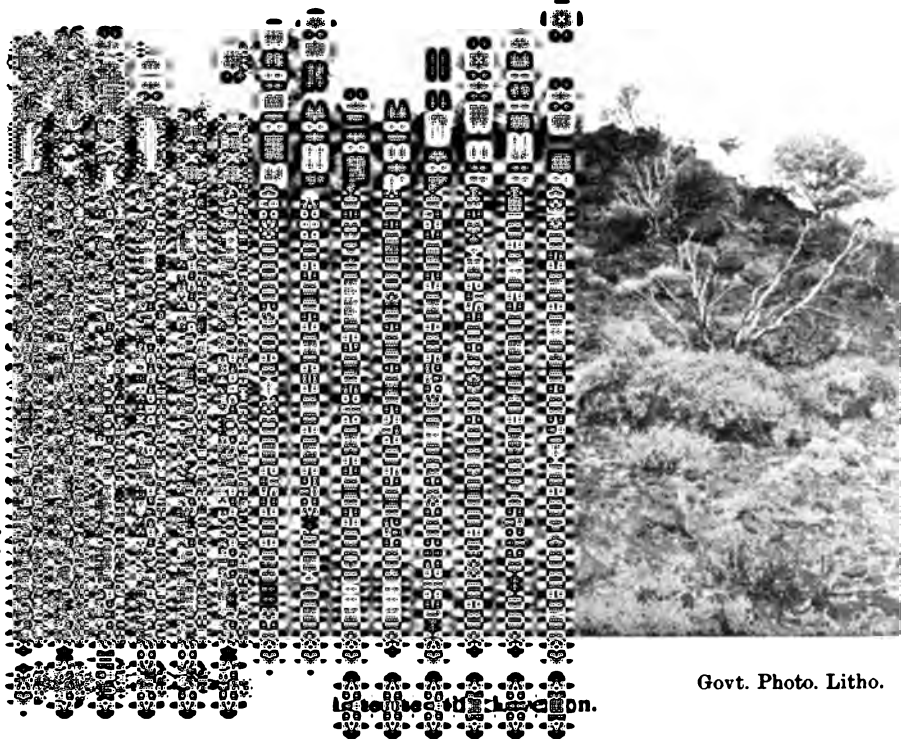
**The Recent Deposits.**—These cover by far the greater portion of the area under examination to depths varying from a few inches to probably 50 or 60 feet, and consist of the accumulated detritus from the older greenstones and granites; where overlying and derived from the former they are of a fine red clayey nature, but when derived from the granite, they are much looser, more sandy and lighter in colour, this difference in appearance being often the only guide as to the nature of the underlying rocks. The boundaries

between these superficial deposits and the outcropping rocks, as shown on the map, are for the most part only approximate, as the point at which the former cease is very indefinite, and is generally purely arbitrary.

The deposits of ironstone gravel (laterite) which form so conspicuous a feature on most of the Eastern Goldfields are not developed to any large extent in this district; a few small isolated patches occur as the cappings of low weathered greenstone hills, principally towards the southern portion of the area examined, but they are, as a rule, of inferior grade. As to the origin of these laterites, it is generally agreed that they have resulted from the gradual concentration and deposition of iron oxide resulting from the weathering of the older basic rocks *in situ*. Almost the only high-grade deposit in the district occurs as the capping of a low greenstone hill about half-a-mile south-east of the old Mount Barnicoat G.M. (*Photograph 1.*)

*The Granitic Rocks.*—These vary through felsites, felspar porphyries, and granites, and are found as intrusive dykes and masses in the greenstones, being most largely developed in the northern portion of the district near Mount Crawford, and also to the westward of the Augusta G.M., where they are evidently portions of the extensive mass lying to the east of Mount Morgans. A specimen [6535], from the eastern side of the main body east of Mount Crawford, near G.M.L. 126, is a dark massive variety very closely resembling a coarse-grained quartz diorite in appearance; under the microscope, however, a section shows it to be a fairly typical granite, consisting, in addition to quartz and felspar, of both biotite and hornblende, both considerably weathered and altered, the latter into a green chloritic material, and the former partially into hornblende. Going westerly this has the appearance of passing gradually through all stages from a dark hornblende granite, or quartz diorite, to a light-coloured quartz porphyry. Sections of specimens [6534, 6533], of these show them to be practically the same rock, the only difference being that the hornblende is less in quantity in the more western variety. In the vicinity of the Augusta G.M., the prevailing type is a fairly coarse-grained rock, ranging from an aplite to a quartz porphyry; the smaller dykes, however, are usually of fine grained, compact felsites and rocks not unlike quartzites.

*The Greenstones.*—The group of rocks to which the general term greenstone has been applied is of by far the greatest economic importance of any in the district, as it is almost solely within them that the auriferous ore bodies are found. These rocks occupy by far the greater portion of the area examined, and consist of both massive and foliated varieties, though it has not been possible to separate the two on the map. It is also possible that there may be more than one variety of basic or ultra-basic rock, but no more



Govt. Photo. Litho.

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than structural distinctions can be observed—a coarse-grained, a fine-grained and a schistose variety being most prominent; the areas occupied by each are not sufficiently well-defined for separate mapping, nor is there any satisfactory evidence with regard to the geological relation of the several varieties, and it has been assumed, as on the other goldfields, and probably correctly, that they are merely local variations of one and the same basic or ultra-basic rock; sections of them show them to be essentially hornblende rocks, ranging through almost typical diorites to a fine-grained rock, consisting almost entirely of hornblende; in the coarser-grained specimens [6527] the hornblende is a very pale to colourless variety (tremolite), and in the fine-grained it is a light to dark green variety (actinolite).

These greenstones are for the most part considerably decomposed and weathered, such weathering being greater on the eastern side of the district, along the Ida H. and Cock of the North line of country, where there has been considerable north and south foliation and a large and well-defined development of the remarkable banded and hematite-bearing quartz lodes, together with the accompanying leaching of the surrounding rocks. This line of country apparently marks a main line of jointing extending over a width of half-a-mile or so, and extending roughly north and south through the Ida H., Cock of the North, and Scotland Yet leases for seven or eight miles.

About two miles west of Ida H. is an outcrop of hard, massive hornblende rocks apparently closely allied with those forming the auriferous series and differing from them only in their hard and unweathered appearance; they form a ridge of low, bare hills occupying a comparatively small area and rising to a height of 30 to 50 feet. An analysis of this rock [6540] made in the Departmental Laboratory is as follows:—

|                     |    |    |    |    |    |             |
|---------------------|----|----|----|----|----|-------------|
| Silica              | .. | .. | .. | .. | .. | 59.35       |
| Carbonic anhydride  | .. | .. | .. | .. | .. | .06         |
| Titanium dioxide    | .. | .. | .. | .. | .. | .78         |
| Combined water      | .. | .. | .. | .. | .. | .83         |
| Soda                | .. | .. | .. | .. | .. | 3.38        |
| Potash              | .. | .. | .. | .. | .. | .90         |
| Magnesia            | .. | .. | .. | .. | .. | 4.58        |
| Lime                | .. | .. | .. | .. | .. | 6.43        |
| Manganese protoxide | .. | .. | .. | .. | .. | .33         |
| Iron protoxide      | .. | .. | .. | .. | .. | 1.76        |
| Iron peroxide       | .. | .. | .. | .. | .. | 5.41        |
| Alumina             | .. | .. | .. | .. | .. | 15.83       |
| Pyrites { iron      | .. | .. | .. | .. | .. | .03         |
| { sulphur           | .. | .. | .. | .. | .. | .04         |
| Hygroscopic water   | .. | .. | .. | .. | .. | .07         |
|                     |    |    |    |    |    | <hr/> 99.78 |
| Specific gravity    | .. | .. | .. | .. | .. | <hr/> 2.86  |

The greenstones are traversed by occasional dykes of newer greenstones, these can seldom be followed on the surface, but are met with in the mine workings; one [6556] cut in the workings of the Ida H. G.M. is some 20 feet in thickness, and runs approximately east and west, being almost vertical in its dip; there is a moderately coarse-grained, dark massive rock, a section of which, seen under the microscope, shows it to be an augite dolerite, showing phenocrysts of augite in a holocrystalline ground mass of small lath-shaped feldspars and granules of augite and magnetite.

These dykes are newer than the quartz reefs and hematite-bearing quartz lodes which they cut through, but without displacing them to any extent.

*Ore Deposits.* — These are conveniently divisible into two classes:—

- (a.) Lodes which are genetically similar to the banded and hematite-bearing quartz lodes, which form so conspicuous a feature of the Murchison and Mount Margaret Goldfields.

- (b.) Quartz reefs of the normal type.

In this respect they exactly resemble those of Mount Morgans, which have already been described by Mr. Jackson in Bulletin 18 of the Geological Survey.

The former are most highly developed immediately to the west of the town along the main ridge, where they occur in a series of bold outcrops extending for several miles. They are identically similar to the hematite-bearing quartz lodes ("quartzites") of the Murchison Goldfield, where they extend as roughly parallel bars, often continuous for many miles in length: they are usually from one to three chains in width, and outcrop in the form of rough serrated ridges. These bands are merely quartz reefs or lodes of a peculiar type, and vary in composition from almost pure quartz, through varieties of banded jaspers, often of great beauty, to practically pure banded hematite. \* They have already been described in detail in earlier Bulletins (Nos. 8 and 14)—

"as old fault or joint lines along which the greenstones have been highly foliated . . . and by a gradual lode forming process converted into their present state."

At Laverton they are found in all gradations, from banded quartz and hematite, through pure banded quartz to bands of practically unaltered schist. They are all more or less auriferous, but only in very few cases are they sufficiently so to pay for working. Examples of this type of deposit are being worked at the Craggiermore, Lancefield, and Great Bedford (Cock of the North) gold mines. These particular deposits will be more fully described when dealing with the individual mines. They usually have a more or less

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\* Bulletin No. 16, p. 25.

lenticular form on the surface, these lenses varying in length from a few chains to half-a-mile or more, and having an average width of from 20 to 100 feet. The deposits along the Ida H. and Cock of the North line have this form to a very marked extent, and on this line they show a greater variation in their appearance and composition than elsewhere, varying from banded ferruginous quartz to a soft ironstained weathered schist, usually silicified and hard near the surface, and often with a capping of hard siliceous limonite.

A good example of non-ferruginous type is seen in the belt forming the ridge of which Mount Crawford is the highest point; there the main bar which forms the apex of this hill has a width of from 2 to 3 chains, and consists of almost pure compact blue and white quartz. This belt extends fairly continuously for about a mile and a half, but becomes a good deal more broken and irregular at its northern end; it also becomes much more ferruginous here.

Quartz reefs of the normal type are often associated with these hematite-bearing lodes, being as a rule small, and usually running along either foot or hanging wall; they are evidently of later formation than the lodes, and are often found cutting across them and sometimes longitudinally through them. Reefs of this type are being worked at the Ida H. and Augusta G.M.s.

Not many reefs of the second class, i.e., normal quartz reefs, are being worked in this district; a fair number occur, some of them being of very fair size. Some of the best types of this class are found at the northern-end of the district on G.M.L. 1291 and 1095, near what was originally known as Crawford's Patch. These reefs occur in massive greenstone, and are of white, somewhat ironstained quartz; they are of fair size and can be traced on the surface for some distance; several small leaders run into these main lines of reef, and it has been in these and at their junction with the main lines that the gold has been got, the stone in the leader at the junction being usually "dollying" stone. The main reefs themselves, though fair sized and well defined as far as tried, are too poor to pay for working.

There are also a fair number of large sized quartz reefs occurring along the junction of the granites with the greenstones; these are, however, for the most part, short and irregular, and are apparently very low in their gold contents, as little or no work has been done on any of them.

*Alluvial Gold.*—Not much alluvial gold has been got in the district. A little was got on the western fall of the main ridge near the old British Flag G.M. The gold in this case was probably derived from small quartz leaders associated with the hematite-bearing lodes. Most of the alluvial has been got, however, at what was known as Crawford's Patch, half to three-quarters of a mile south-east of

Mount Crawford. Here a fair amount of dry-blowing has been done, but the gold appears to be nearly all worked out. It was got mostly at a depth of only a few inches, and has probably been derived from small quartz leaders both in the greenstones and the granitic rocks and from leaders associated with quartz reefs in the greenstones, such as those worked on G.M.Ls. 1291, 1095, and 1601.

*Water.*—Water is fairly plentiful throughout the district, and the supply is generally fresh, the town depending upon wells for its supply for domestic purposes.

*Timber.*—Timber of good quality is not plentiful, and is rapidly becoming exhausted.

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### The Mines.

THE LANCEFIELD G.M.L. 806, etc.—This is the largest and most important mine in the district, and is situated some five miles north of Laverton townsite. At the time of my visit, the mine was equipped with a 50-head stamper battery, concentrators, and leaching and filter press plants. (*Photographs 2 and 3*). Owing, however, to difficulty in ore treatment, the use of the present plant is to be discontinued and a dry crushing and roasting plant to be installed in its place. This, it is hoped, will prove highly successful and give an impetus to mining generally throughout the district.

The workings are on a large banded quartz lode (Fig. 1) trending about north-east and south-west, and dipping at an average angle of about 40 degrees to the south-east. From an examination of the mine plans (Plate A.) it will be seen that, though a very considerable amount of stone has been taken out, the mine is still in its infancy, having only been opened up to a depth of 300 feet on the underlay. The ore body consists of banded and hematite-bearing quartz, presenting in the upper level almost the appearance of a normal quartz reef with a strongly marked laminated structure, apparently with fairly well defined walls, though the country is too decomposed and rotten to see much here. As the unoxidised and unaltered zone is reached it is seen that there are no hard and fast walls to the lode, but that it is encased on both sides by about 30 feet of greenstone schists, which, in places, approach in appearance very close to the lode proper. In the 300-foot level, the lode consists of alternating bands of quartz and altered schist, carrying a large percentage of arsenical pyrites, usually arranged in roughly parallel zones with the quartz. As a rule the quartz largely predominates, often to the complete elimination of the schist, having in these cases a banded dark grey appearance, frequently seamed with small veinlets of calcite; in other cases the schist predominates over the quartz,



Govt. Photo. Litho  
Laverton.





Govt. Photo. Litho.  
Laverton.



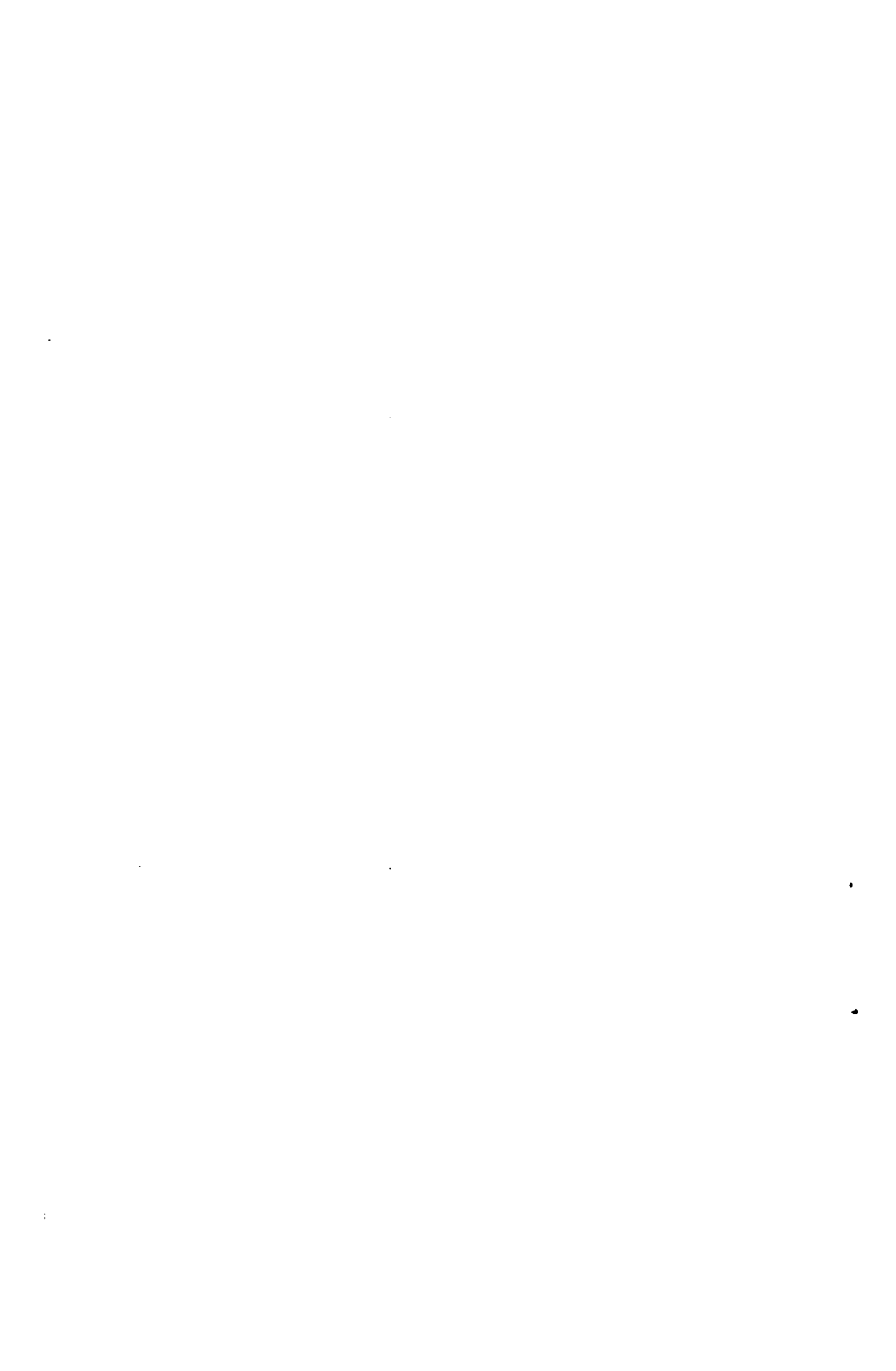


FIG 1.

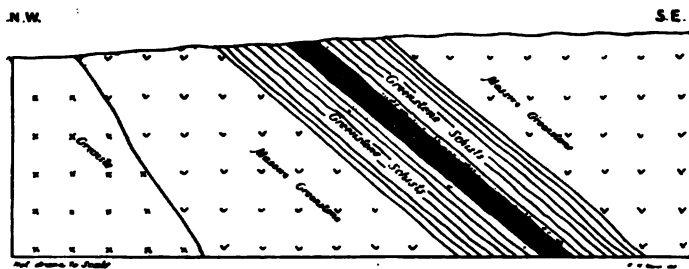


DIAGRAM: SHEWING MODE OF OCCURRENCE OF LODGE ON LANCEFIELD G.M.L. 806 LAVERTON D.S.C. MT MARGARET G.E.

FIG 2.

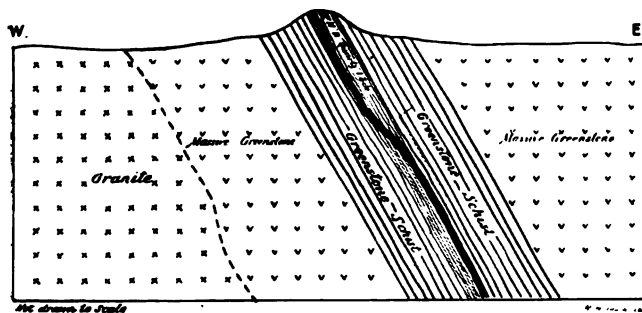
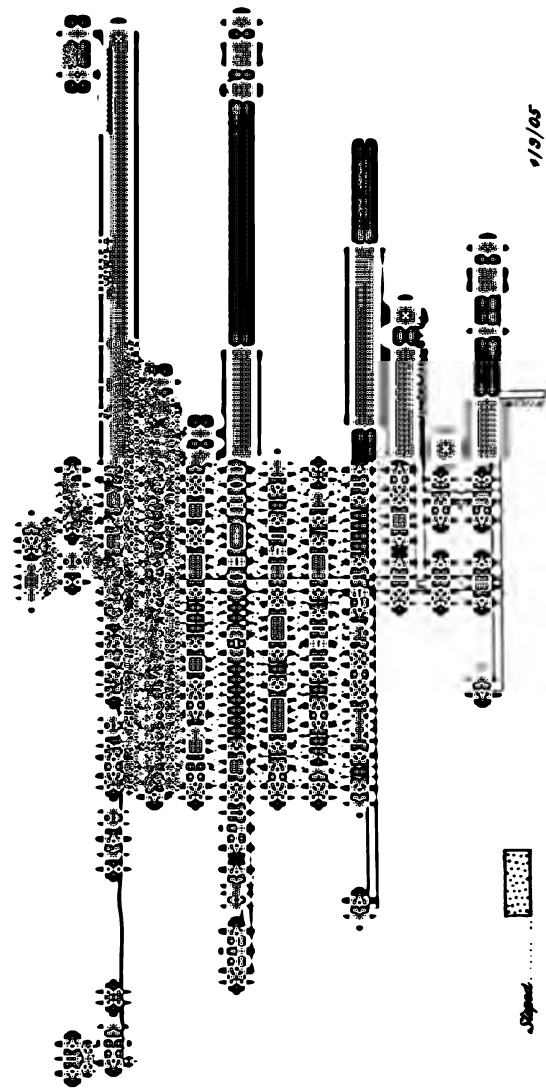
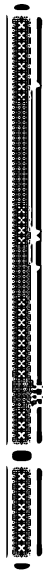


DIAGRAM: SHEWING MODE OF OCCURRENCE OF REEF ON AUGUSTA G.M.L. 371 LAVERTON MT MARGARET G.F.





*Original*

4/13/05

SKETCH SECTION OF AUGUSTA G.M.L. 371. LAVERTON MARGARET G.F.

Scale of Feet

*P.L. Irving del.*

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in which case there is no defined limit between the lode proper and the enclosing schistose greenstone; the gold contents, too, usually drop somewhat in these cases, being as a rule highest where there is most quartz present. The lode, generally speaking, has an average thickness of about 17 feet, though it varies a good deal on either side of this, being as much as 25 feet in places in the bottom level, while again in the north face of the 200-foot level, it is down to three feet; this, however, is exceptionally small. The gold contents right through the workings are remarkably uniform, and the shoot has been proved for over 1,000 feet in length, and its exact limits are not yet known. A reference to the accompanying plan (Plate A.) will show the sizes of the lode at the different levels. (The width at the 100-foot level and the surface being taken from old reports, are only approximate.) The zone of oxidation stops a little above the 200-foot level, there being a small percentage of sulphide in the stone from this level; below this the sulphides come in very heavily, and consist for a great part of arsenical pyrites, this being the chief difficulty in the treatment of the ore. A little graphitic schist is occasionally found on the walls of the lode, but it is very limited in extent. The original water level was probably the first (100 feet) level, being a vertical depth of about 60 feet. The supply is fresh. One or two faults cross the lode in a general east and west direction; these, however, do no harm, their throw being only a few feet. In the south end of the workings, in the 200-foot level, the reef is cut off and broken by the intrusion of a granitic dyke; there is no sign of this in the 100-foot level, but it will probably be met with in the bottom workings.

It will be seen, on reference to the accompanying plan (Plate A.), that there is still a very large quantity of stone available, even above the 300-foot level, and when the large amount of backs for every 100-feet of sinking is taken into consideration, it can easily be seen that, should the difficulty of satisfactory ore treatment be overcome, there must be a long and prosperous future before this mine.

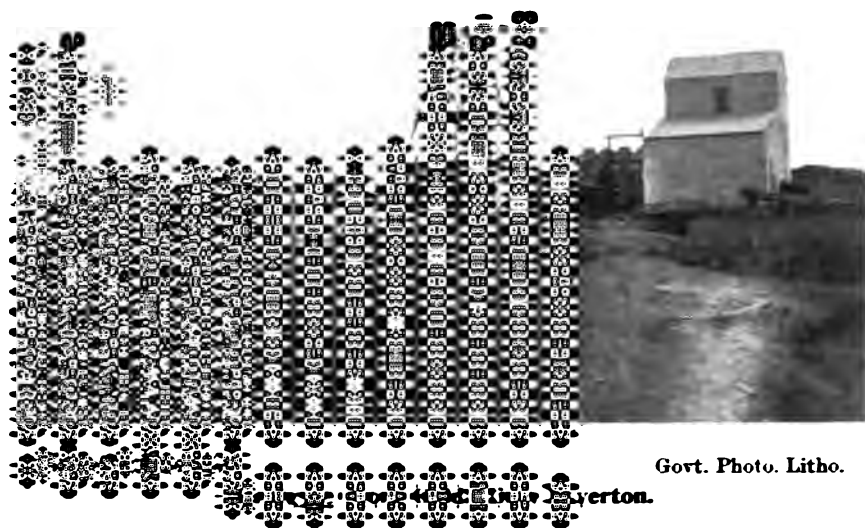
*Lancefield G.M. Co., Ltd., G.M.Ls. 806, etc.*

| Year.         | Ore crushed. | Gold therefrom. | Rate per ton. |
|---------------|--------------|-----------------|---------------|
|               | tons.        | fine ozs.       | ozs.          |
| 1899 .. .. .  | 6,110.00     | 2,056.67        | .33           |
| 1900 .. .. .  | 11,701.00    | 5,639.75        | .48           |
| 1901 .. .. .  | 16,847.00    | 6,256.55        | .37           |
| 1902 .. .. .  | 20,781.00    | 7,780.60        | .37           |
| 1903 .. .. .  | 21,928.00    | 7,068.29        | .32           |
| 1904 .. .. .  | 25,154.78    | 10,733.91       | .42           |
| 1905 .. .. .  | 47,693.00    | 15,373.32       | .32           |
| Total .. .. . | 150,214.78   | 54,909.09       | .36           |



CRAIGGIEMORE, G.M.L. 592.—As can be seen from the accompanying plan (Plate B.) of this mine, a large amount of work of a somewhat irregular nature has been done. (*Photograph 4*). In all three different ore bodies have been worked, known respectively, as the Eastern, Middle, and Western; of these, the Eastern and Middle, in the bottom level, are apparently one and the same; the Western lies a chain or so farther to the west. These so-called separate lodes are apparently merely shoots of pay ore in the one large lode, the whole country here over a width of 150 to 200 feet consisting of a very much crushed and altered greenstone, carrying more or less gold throughout. Portions of this zone are more highly altered than others, and on the surface have the appearance of the usual hematite-bearing quartz lodes; a little below the surface, they become soft and consist apparently of weathered bands of schist and ironstone with more or less quartz; in some cases, when the quartz largely predominates, these bands assume a solid well defined character, in others again they are of a very sintery nature. Occasionally these bodies take the form of the typical compact banded hematite-bearing quartz lodes, in which cases their gold contents are usually slightly lower; as a rule, the best values are obtained in the sintery bodies. As may be expected, there are no hard and fast walls between these pay shoots and the enclosing schists, the whole being, as before stated, practically one large lode formation. At present there has not been sufficient work done to determine the exact size and relationship of the pay shoots, they are, however, very irregular; the western one has been proved for about 100 feet south and 200 feet north of the shaft, and is still going north; the extent of the other makes is not known.

The values in these shoots varies a good deal, a lot of the stone not being good enough to take out, and the workings are very irregular on this account, the stone simply being extracted where it has been found rich enough to pay for working; in the upper levels the stopes vary from 15 to 30 feet in width on all the ore bodies; in the lower level all the work is at present being concentrated on the western lode, which is being stoped out for a width of about 15 feet. The country and the ore bodies dip almost vertically, but the latter pitch fairly flat to the northward. The whole country is very soft and rotten all through the present workings, and just begins to get hard and settled at the 300-foot level, at which point a fair amount of sulphide begins to make its appearance in the stone. The ore bodies worked on this property are in every way similar to the hematite-bearing quartzites occurring all along the main ridge through this lease to Laverton, and it seems not unreasonable to presume that there are other payable bodies of stone along this line as yet undiscovered. Other bodies along the line have been worked on the British Flag lease, and also one or two other leases between Craggiemore and Laverton, but so far with not very satisfactory results.



Govt. Photo. Litho.

verton.



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*Craiggiemore Proprietary, G.M.L. 592T, etc.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Average.      |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | Tons.        | Fine oza.       | oza. per ton. |
| 1897  | .. | .. | .. | 10.00        | 13.01           | 1.30          |
| 1898  | .. | .. | .. | 205.00       | 171.93          | .83           |
| 1899  | .. | .. | .. | 1,020.00     | 296.53          | .29           |
| 1900  | .. | .. | .. | 9,260.00     | 3,641.24        | .39           |
| 1901  | .. | .. | .. | 14,200.00    | 5,070.67        | .35           |
| 1902  | .. | .. | .. | 14,000.00    | 4,652.08        | .32           |
| 1903  | .. | .. | .. | 13,700.00    | 4,382.42        | .32           |
| 1904  | .. | .. | .. | 14,769.00    | 3,958.60        | .27           |
| 1905  | .. | .. | .. | 18,152.00    | *7,640.44       | —             |
| Total |    |    |    | 85,316.00    | 29,826.92       | .35           |

\* Includes 3,297.09 by cyanide.

AUGUSTA, G.M.L. 371.—This lease is situated about four miles to the west of Laverton, and was once the property of the Golden Rhine G.M. Co.; it was abandoned by them after a good deal of work had been done on it, and recently taken up again by the present owners, who, up to the present time, are doing very well out of it. The workings are on a quartz reef of the normal type, which runs alongside and through a band of highly altered greenstone schist (Fig. 2), in which, on or near the surface, alteration has gone on so far that it has been converted into a typical banded hematite-bearing quartz lode. At the surface the reef is on the footwall of this band, but cuts through it at about 240 feet and then runs on the hanging wall. The country on both sides of the reef is greenstone schist, all in a more or less altered state; at about 250 feet, the belt of altered schist which forms the footwall of the reef gets extremely hard, and continues so to the bottom of the main shaft (300 feet); this is evidently the continuation in depth of the hematite-bearing quartz lode seen on the surface, being here in merely a half-formed state, consisting of greenstone schist highly charged with infiltrated hematite and quartz. The country surrounding the schists is, at the 300-foot level, very hard and massive, and consists of a fine grained greenstone [6558], a section of which, seen under the microscope, shows it to consist essentially of pale green hornblende and triclinc felspar in small irregular lumps and grains, the hornblende occupying the greater part of the section, and in addition numerous small scattered grains of magnetite.

The reef itself is not at all regular, and varies in thickness from a mere thread up to as much as six feet, which is its thickness in the north face of the 300-foot level; it has no well-defined walls, and merely fills irregular cracks and hollows in the schists. It dips, with the schists, at an angle of about 45 degrees to the east and strikes a little to the west of north; it does not, however, keep a very straight course, but twists about a little. A good deal of graphitic schist

is found on the footwall of the reef in the 300-foot level ; this only occurs over a length of about 20 to 30 feet, and can be traced right to the surface, having an average thickness of 12 to 18 inches. The quartz is very clean and white, and very hungry looking ; in places, however, it shows fairly coarse gold freely.

The present owners are working a rich shoot of stone near the north end of the bottom drive (Fig. 3). This shoot has been followed down by means of a winze to a depth of about 40 feet ; the average width of the reef in this winze is about two feet and it shows coarse gold and telluride freely over a depth of about 25 feet ; in the bottom of the winze it is smaller and much split and broken up. This shoot of ore at present being worked was cut in the 300-foot level, and here had a length of about four feet, this being just the top of the shoot, and dips to the north at a fairly flat angle. Some of the stone taken out was phenomenally rich, and showed, in addition to free gold, a thin white telluride, which an examination in the Departmental Laboratory proved to be Altaite (telluride of lead). This occurrence is interesting from the fact that this is one of the very few places in Western Australia, outside Kalgoorlie, from which an authentic discovery of telluride has been reported.

Water is not too abundant ; it is, however, drinkable, and is also used for the boilers.

The mine is equipped with a 10-head battery.

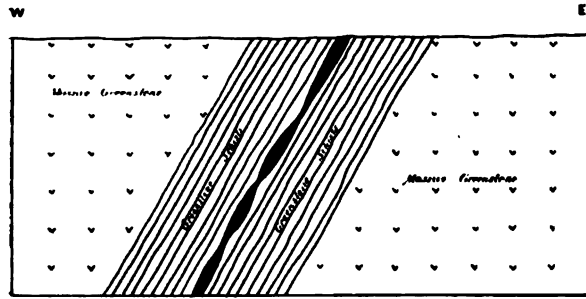
The sketch section (Fig 3), showing approximately the amount of work done, is prepared from figures supplied, from memory, by the present manager, the existing underground plans not being available.

*Augusta, G.M.L. 371, late Golden Rhine G.Ms. G.M.Ls. 371 (777, 764, 1249).*

| Year.       | Ore crushed.     | Gold therefrom.  | Rate per ton. |
|-------------|------------------|------------------|---------------|
|             | tons.            | fine ozs.        | ozs.          |
| 1897 .. ..  | 50.00            | 167.20           | 3.34          |
| 1898 .. ..  | 391.50           | 1,099.99         | 2.81          |
| 1899 .. ..  | 1,774.00         | 1,904.07         | 1.07          |
| 1900 .. ..  | 630.00           | 496.64           | .78           |
| 1901 .. ..  | 8,091.00         | 5,121.30         | .63           |
| 1902 .. ..  | 3,711.00         | 1,838.62         | .49           |
| 1903 .. ..  | 850.00           | 430.93           | .53           |
| 1904 .. ..  | —                | —                | —             |
| 1905 .. ..  | 834.00           | 1,659.43         | 1.98          |
| Total .. .. | <b>16,331.50</b> | <b>12,718.18</b> | <b>.77</b>    |

**BINDAN AND CORNUCOPIA, G.M.Ls. 1588, 1601.**—These leases are situated about three and a-half miles north of Laverton town-site, and consist of two six acre-blocks, situated on a well-defined line of lode running about north-west and south-east. This line

FIG. 4.



not shown to scale

100 feet

DIAGRAM - SHOWING MODE OF OCCURRENCE OF REEF ON LITTLE DORE 6 N. 17 E. ERIKSTOWN, WYOMING 6 7





of lode consists of a belt of highly foliated greenstone schists some 15 to 20 feet in width, and dipping steeply to the south-west. Through this belt of schist, numbers of irregular quartz leaders run in all directions; these vary in size from 1 to 12 inches, and some of the smaller ones often carry a big percentage of gold; the majority of them, however, are barren or close to it; small patches of rich stone are often found at the intersection of the small leaders, or at points where they coalesce with the larger; these are invariably dollying stone, but not much more than a few ounces is usually obtained from them. On the Bindan lease an open cut has been made on this band of schist over practically its entire width, to a depth of about 12 to 14 feet, and for a length of some fifty yards, for the purpose of working out the rich leaders and pockets, but no work of any importance beyond this has been done. On the Cornucopia, especially near the southern end, there are two well defined fair sized lines of reef running through and parallel with this formation; these are of white quartz and are as much as two or three feet in places; they intersect near the centre of the lease and die out a chain or so farther on. A little work has been done in these but they were too low grade to be of any use; a small rich pocket was obtained at the junction, one or two small pockets have also been obtained at the points at which small leaders run in these reefs; as is the case on the adjoining lease, most of the gold on this block has been obtained from small leaders, and has been obtained at a depth of less than 12 feet from the surface, this being the depth at which most of the gold-bearing leaders cut out. A few chains to the east of G.M.L. 1588 is a similar belt of schist traversed by numerous small quartz leaders: a little work has also been done on these, but they do not appear to have been as rich as those in the western belt. A fair amount of dry-blowing has been done in the vicinity of these leases, and the gold has undoubtedly been shed from small leaders in these and similar belts of schist.

During 1905, the crushings from this lease (Cornucopia, G.M.L. 1601) were 15.00 tons for 39.08 ounces, giving an average of 2.60 ounces per ton.

IDA H., G.M.L. 829, etc.—Next to the Lancefield, this is the most important mine in the district, and, as can be seen from the accompanying section (Plate C.), a very considerable amount of work has been done upon it. The workings are on a fair sized but irregular quartz reef, which runs in and parallel to a belt of highly altered greenstone schists. This belt of schists on the surface has been partly altered into a solid hematite-bearing quartz lode, which can be followed for a considerable distance; this, however, is merely a surface formation, as at the 100-feet level it has entirely disappeared, and the schists are of a soft decomposed and iron-stained appearance with occasional small seams of ironstone running through them. These schists are found on both sides of the reef and in close proximity

to it, often carry a small quantity of gold, but not sufficient to be payable. Small quartz leaders up to a couple of inches in thickness are often found traversing the schist, usually running parallel to them; these, though often auriferous, are usually too small and irregular to be of any value. In the lower levels these schists carry a considerable quantity of sulphide ore, and at the 300-foot level are several bands of solid massive pyrites up to two or three feet in thickness running parallel to the reef, one along the footwall and two others some 8 and 20 feet respectively to the east of it. These sulphide lodes are apparently merely replacements of the schists, and evidently correspond with the "ironstone bands" in the upper oxidised zone; they carry a little gold but not sufficient to render them of any value.

One or two augite-dolerite dykes cut across the reef and the surrounding schists in an east and west direction; the largest of these is about 600 feet north of the main shaft and some 20 feet in thickness, and is vertical. The reef is merely cut in two by these dykes and not thrown or displaced in any way; the stone, however, is usually of a little better grade in proximity to the dykes.

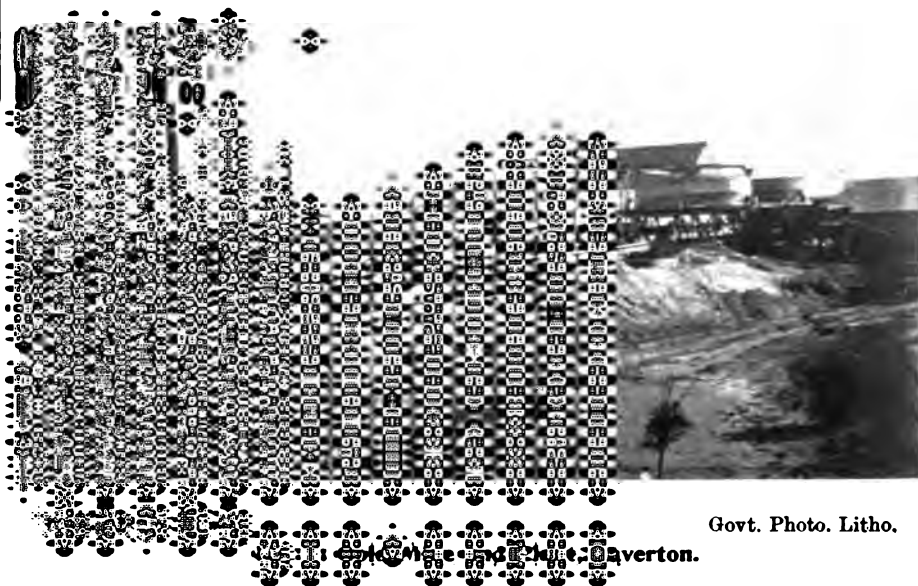
The reef itself is of clean white quartz, and, as can be seen from the accompanying section (Plate C.), has been followed for nearly 1,600 feet; it runs in a nearly north and south direction, and dips at an angle of about 60 degrees to the eastward; in size it is somewhat irregular, being as much as six feet in thickness in places, while in others it dies out to nothing, the quartz being replaced by schist which is practically identical with that forming the walls; this schist is itself of no value, but it is often seamed with small quartz veins, in which case it is usually sent to the battery; taking the reef right through, its average thickness is about two feet. The gold contents are not uniform over the entire length, the extent of the pay shoots being shown on the accompanying section of the workings; it will be seen from this section that the developments at the 400-foot level tend to prove the continuance at a depth of the northern shoot, and should the 500-foot level, when opened up, prove its further existence, it will mean a period of renewed prosperity for this mine.

The stone in the lower levels carries only a small amount of sulphides, these beginning to make their appearance at the 300-foot level; the limit of oxidation is not regular, being deeper on the north side of big greenstone dyke; there was also a much heavier supply of water on this (northern) side of the dyke. In the 400 foot level, a little zinc blende is found in the quartz, the gold contents being usually higher where this occurs. The water in the mine is salt, and water for boiler and cyanide and domestic purposes is obtained from a well at Mount Barnicoat, about two-and-a-half miles north.

The mine is equipped with a ten-head battery and cyanide plant.  
(*Photograph 5.*)

Bulletin 24.

Govt. Photo. Litho.





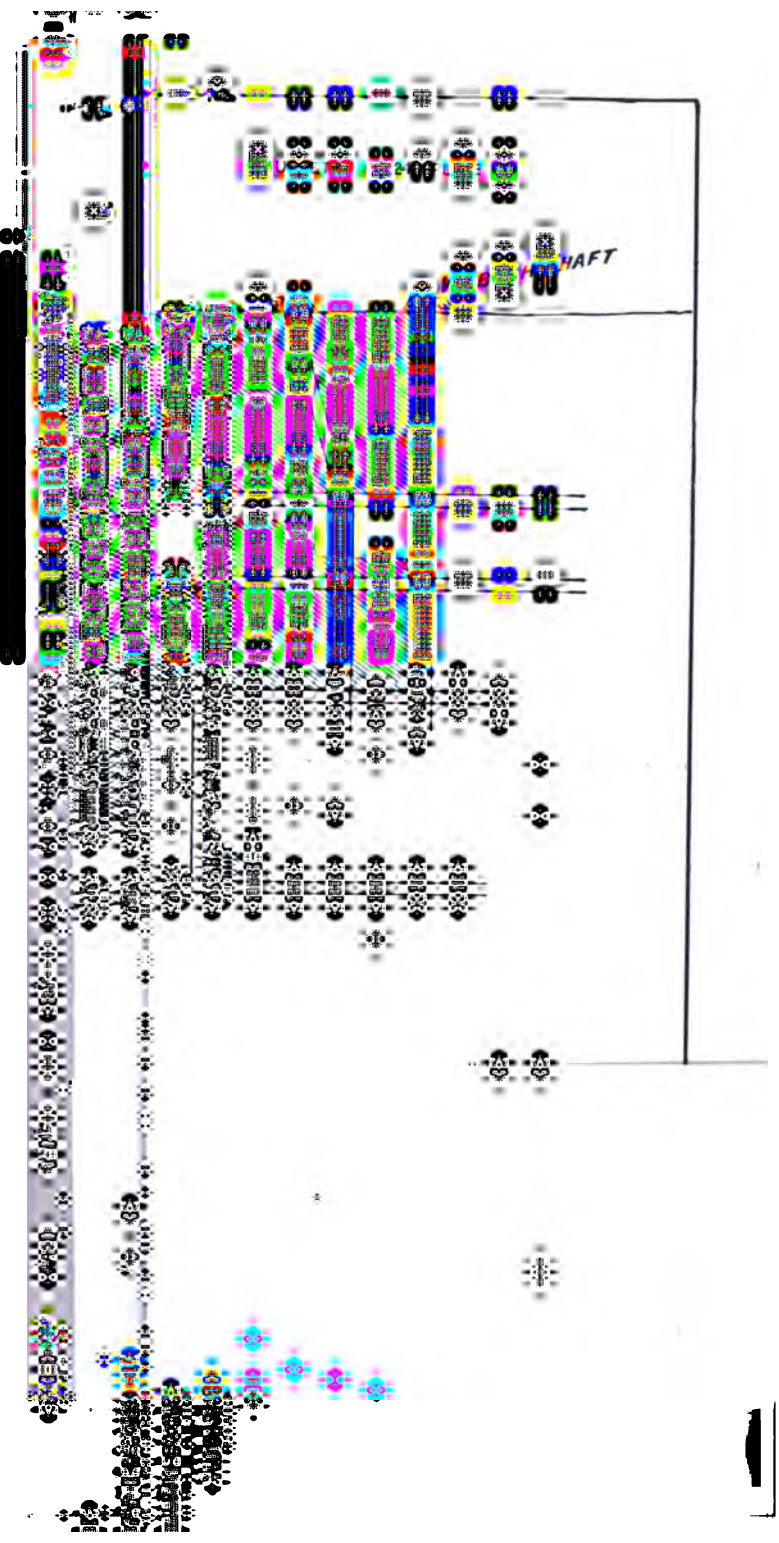




*Table showing the total gold yield from the Ida H. G.M., G.M.Ls.  
829, 846, 1219, 1310, 838.*

| Year.         | Ore crushed. | Gold therefrom. | Rate per ton. |
|---------------|--------------|-----------------|---------------|
|               | tons.        | ozs.            | ozs.          |
| 1899 .. .. .  | 81.00        | 235.37          | 2.90          |
| 1900 .. .. .  | 30.00        | 49.76           | 1.66          |
| 1901 .. .. .  | 1,858.00     | 1,817.08        | .97           |
| 1902 .. .. .  | 11,319.00    | 12,346.65       | 1.09          |
| 1903 .. .. .  | 13,017.00    | 12,856.44       | .91           |
| 1904 .. .. .  | 14,610.00    | 12,369.91       | .84           |
| 1905 .. .. .  | 16,713.00    | 11,902.52       | .71           |
| Total .. .. . | 57,628.00    | 51,577.73       | .89           |

IDA H. CONSOLS, G.M.L. 1623.—Three shafts have been sunk on this property, one vertical and two underlay, all to a vertical depth of 130 feet; an underlay winze has been sunk to a further depth of 40 or 50 feet; the reef has been worked out from the 130 feet level to the surface for a length of about 110 feet, commencing from a point some 20 feet south of the south underlay shaft. A little work was being done at the north end of the bottom workings at the time of my visit. The reef, which runs along the hanging wall side of an "ironstone bar" hematite-bearing quartz lode, strikes about north and south and dips to the eastward at an angle of about 60 degrees; it is of clean white quartz, and averages from 6 to 15 inches in width; at the south end of the bottom workings it has pinched to a mere thread, but makes again farther on, as it has been worked on the adjoining property, the White Horse, to a depth of 130 feet, and apparently a good deal of work has been done on it here; these workings were, however, inaccessible at the time of my visit.

The country consists of greenstone schist, and is very soft and rotten. The water level is at about 130 feet vertically below the surface.

*Table showing the Yield of the White Horse Reef.*

| Year. | Name and Number of Lease.          | Gold crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|------------------------------------|---------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                    |               |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                    | tons.         | fine ozs.       | ozs.          | tons.        | fine ozs.       | ozs.                  |
| 1902  | White Horse, G.M.L. 854 ...        | 67 00         | 36 97           | .55           |              |                 |                       |
| 1903  | Do. do. ...                        | 61 50         | 35 37           | .57           |              |                 |                       |
| 1904  | Do. do. ...                        | 29 00         | 22 04           | .75           |              |                 |                       |
|       |                                    |               |                 |               | 157 50       | 104 28          | .66                   |
| 1903  | Ida H. Consols, G.M.L. 1623 (1949) |               |                 |               |              |                 |                       |
|       | late Ida H. North Extended, 1949   | 111 00        | 164 61          | 1 48          |              |                 |                       |
| 1903  | Do. do. ...                        | 236 50        | 183 80          | .81           |              |                 |                       |
| 1904  | Do. do. ...                        | 53 00         | 14 90           | .29           |              |                 |                       |
| 1905  | Do. do. ...                        | 35 00         | 7 77            | .22           |              |                 |                       |
|       |                                    |               |                 |               | 434 50       | 375 28          | .84                   |
|       | Total ...                          | ...           | ...             | ...           | 592 00       | 379 56          | .64                   |



GREAT BEDFORD, G.M.L. 1042 (late Cock o' the North).—An extensive belt of greenstone schists runs on a bearing slightly west of north and east of south through this property and the adjoining ones, portions of it being altered into the typical hematite-bearing quartz lodes; these vary in width, on the surface, from a couple of feet to nearly a chain, and run with the schists, dipping with them at a steep angle to the westward. These lodes present on the surface a somewhat lenticular form and are very hard and compact, often rising in the form of low rough ridges, which can be traced across country in a more or less interrupted line for over a mile. This hard silicified form does not generally extend to any great depth, being to a great extent only a surface alteration, but at a comparatively shallow depth gradually gives place to soft altered and sometimes ironstained schist with occasional thin seams and stringers of quartz running through it; there is, however, one well defined hematite-bearing quartz lode continuing in depth; this is met with in the northern workings where it has a thickness of about 30 feet. All the workings on the lease are in this belt of schist, which in reality forms one immense lode, some parts of which have undergone greater alteration than others, and are higher in their gold contents. The workings consist of a main shaft, which at the time of my visit was sunk to water (200 feet), and from which a few feet of driving had been done at about the 100-foot level on a small body of quartz running parallel to the lines of foliation of the schists; several of these quartz leaders were cut in the shaft, and some of them carry very good values. Most of the work, however, has been done towards the north end of the lease, where several shafts have been sunk on the side of a large outcrop of hematite-bearing quartz. The shaft from which work was being done at the time of my visit was down 75 feet, and a drive had been put in at this level westerly for a distance of 140 feet; 60 feet in from the shaft a winze has been sunk a further 30 feet; this is on the western side of a hard compact hematite-bearing quartz lode ("jasper lode") where there is about eight feet of fairly good ore, consisting of schist highly impregnated with quartz in veins and masses, the quartz often being the full width of the ore body. A similar ore body, four to five feet wide, occurs on the eastern side of the "jasper lode," both being very similar to the main lode, differing only in the fact that they contain more clean quartz and less oxide of iron. A small amount of work has been done on both of these ore bodies.

The western portion of the main drive is in soft, much iron-stained schist with a good deal of quartz coming in near the end, and carrying very fair values in places. The whole of this drive is, carried through one big lode consisting, as stated before, of more or less highly altered greenstone schist, portions of which have undergone greater alteration and are more highly impregnated with quartz than others, and it is in these portions that the best

values are obtained, though the formation carries a little gold throughout its entire width.

The mine is equipped with a Huntingdon mill and winding gear, but at the time of my visit was handicapped by an inadequate water supply; this difficulty, however, would probably be overcome by the deepening of the main shaft.

The continuation of the Great Bedford line of lode is traceable in a fairly continuous line for over a mile northerly, and in one or two places a little work has been done on it with fair success. On the Scotland Yet (Cock of the Walk), a good deal of work appears to have been done on a large banded quartz lode, but, at the time of my visit, the workings had been abandoned and were inaccessible. A little surface work was being done, and a small parcel of stone crushed with very satisfactory results.

*Great Bedford, G.M.L. 1042 (late Cock o' the North).*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1902  | .. | .. | .. | 37.00        | 91.09           | 2.73          |
| 1903  | .. | .. | .. | 33.00        | 14.79           | .44           |
| 1904  | .. | .. | .. | —            | —               | —             |
| 1905  | .. | .. | .. | 82.00        | 24.87           | .30           |
| Total | .. | .. | .. | 152.00       | 130.75          | .86           |

*Cock of the Walk, G.M.L. 1663 (late Scotland Yet, G.M.L. 1253).*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1902  | .. | .. | .. | 115.00       | 47.72           | .41           |
| 1905  | .. | .. | .. | 45.00        | 15.29           | .34           |
| Total | .. | .. | .. | 160.00       | 63.01           | .39           |

The following table, compiled from the official statistics, shows the total gold yield from the leases in that portion to the Laverton district mentioned in the accompanying report, up to the end of 1905:—

| Name and Number of Lease.                                            | Ore crushed.      | Gold therefrom.     | Rate per ton. |
|----------------------------------------------------------------------|-------------------|---------------------|---------------|
|                                                                      | tons.             | fine ozs.           | ozs.          |
| Acrasia, G.M.L. 1616r. .. .. .                                       | 14.00             | 9.85                | .70           |
| Ajax, G.M.L. 828r (790r) .. .. .                                     | 57.00             | 57.43               | 1.00          |
| Alma Mater, G.M.L. 1180r. .. .. .                                    | 631.00            | 680.92              | 1.07          |
| Augusta, G.M.L. 371r .. .. .                                         | 16,331.50         | 12,718.18           | .77           |
| British Admiral, G.M.L. 723r .. .. .                                 | 10.00             | 18.43               | 1.83          |
| British Empire, G.M.L. 1431r (1396r) .. .. .                         | 199.50            | 120.83              | .60           |
| British Flag, G.M.Ls. 1302r (358r) .. .. .                           | 93.00             | *514.35             | —             |
| Broken Pledge, G.M.L. 1513r .. .. .                                  | 20.00             | 4.17                | .20           |
| Cock of the Walk, G.M.L. 1663r .. .. .                               | 160.00            | 63.01               | .39           |
| Cornucopia, G.M.L. 1601r .. .. .                                     | 15.00             | 39.08               | 2.60          |
| Corio, G.M.L. 1439r .. .. .                                          | 7.00              | 4.08                | .58           |
| Craiggiemore Proprietary, G.M.Ls. 592r, etc. .. .. .                 | 85,316.00         | 29,826.92           | .35           |
| Dream, G.M.L. 825r .. .. .                                           | 210.00            | †592.12             | —             |
| Emerald, G.M.L. 1486r .. .. .                                        | 34.00             | 22.09               | .64           |
| Enniskillen, G.M.L. 1453r .. .. .                                    | 96.00             | 17.09               | .18           |
| Federal Flag, G.M.L. 985r .. .. .                                    | 20.00             | 10.17               | .50           |
| Flintlock, G.M.L. 1192r .. .. .                                      | 123.00            | 69.88               | .56           |
| General Wabash, G.M.L. 838r .. .. .                                  | 100.00            | 288.72              | 2.88          |
| Golden Pinnacle, G.M.L. 1459r .. .. .                                | 211.00            | 55.28               | .26           |
| Great Bedford, G.M.L. 1042 .. .. .                                   | 152.00            | 130.75              | .86           |
| Great Britain, G.M.L. 563r .. .. .                                   | 10.00             | 9.26                | .92           |
| Ida H. G.M., G.M.Ls. 829r, etc. .. .. .                              | 57,628.00         | 51,577.73           | .89           |
| Ida H. West G.M.Ls. 1394r (1006r) .. .. .                            | 503.00            | 358.44              | .71           |
| Ida H. Console, G.M.L. 1632r (1249r) .. .. .                         | 424.50            | 271.28              | .64           |
| Just in Time, G.M.L. 1159r .. .. .                                   | 50.00             | 62.35               | 1.24          |
| Kiora, G.M.L. 902r (793r) .. .. .                                    | 366.00            | 357.09              | .97           |
| Kuranin Reefs, G.M.L. 1308r .. .. .                                  | 20.00             | 39.82               | 1.99          |
| Lady Beatrice, G.M.L. 1615r .. .. .                                  | 91.00             | 34.57               | .38           |
| Lady Hopetoun, G.M.L. 1098r .. .. .                                  | 7.00              | 2.68                | .38           |
| Lady Julie, G.M.L. 1605r .. .. .                                     | 8.00              | 16.00               | 2.00          |
| Lancefield, G.M., G.M.Ls. 806r, etc. .. .. .                         | 150,214.78        | 54,909.09           | .36           |
| Laverton, G.M.L. 1490r .. .. .                                       | 39.00             | 11.69               | .30           |
| Lights of Home, G.M.L. 1339r .. .. .                                 | 170.50            | 214.23              | 1.25          |
| Lloyds, G.M.L. 929r .. .. .                                          | 21.00             | 11.05               | .52           |
| Lord Hopetoun, G.M.L. 1095r .. .. .                                  | 25.00             | 3.86                | .14           |
| Little Queen, G.M.L. 1506r .. .. .                                   | 18.00             | 46.07               | 2.55          |
| Maryboro, G.M.L. 1161r .. .. .                                       | 20.50             | 17.44               | .85           |
| Mystery, G.M.L. 1067r .. .. .                                        | 145.00            | 145.78              | 1.01          |
| Menzies Golden Rhine, G.M.s., G.M.Ls. 475r, 660r, 718r, etc. .. .. . | 652.00            | 359.12              | .55           |
| Nous Verrons, G.M.L. 1214r .. .. .                                   | 176.50            | 157.33              | .89           |
| Pat's Find, G.M.L. 1468r .. .. .                                     | 10.00             | 21.97               | 2.19          |
| Rescue, G.M.L. 1518r .. .. .                                         | 10.00             | 3.40                | .34           |
| Rose, G.M.L. 1373r .. .. .                                           | 643.50            | 505.61              | .78           |
| Sons of Toil, G.M.L. 1309r .. .. .                                   | 138.00            | 92.50               | .62           |
| St. Alban's, G.M.L. 1479r .. .. .                                    | 171.00            | 95.02               | .55           |
| Sunny Hill, G.M.L. 1082r .. .. .                                     | 87.00             | 72.52               | .83           |
| Toby, G.M.L. 1426r .. .. .                                           | 9.50              | 42.07               | 4.43          |
| Warrior, G.M.L. 1424r (1159r) .. .. .                                | 30.00             | 34.33               | 1.14          |
| Westella, G.M.L. 1476r .. .. .                                       | 30.00             | 45.52               | 1.52          |
| Wooloomooloo, G.M.L. 1368r .. .. .                                   | 17.00             | 69.07               | 4.06          |
| White Horse, G.M.L. 854r .. .. .                                     | 157.50            | 104.28              | .66           |
| Sundry Claims .. .. .                                                | 963.00            | 708.22              | .73           |
| Laverton State Battery .. .. .                                       | 46.50             | 346.19              | —             |
| District Generally .. .. .                                           | ..                | †58.71              | —             |
| <b>Total .. .. .</b>                                                 | <b>316,702.78</b> | <b>\$155,987.93</b> | <b>.49</b>    |

\* Includes 267.32ozs. dolled and specimens.  
 † Alluvial.

† Includes 68.98ozs. dolled and specimens.  
 § Exclusive of alluvial.



Govt. Photo. Library.

Gartville.



## Burtville.

(With a Geological Sketch Map, Plate IV.)

This centre is situated twenty-four miles south-east from Laverton, and a cleared surveyed road connects the two places. The country passed over by this road is mostly flat, with occasional low ridges of massive greenstone of the usual type, and one or two fair-sized outcrops of hematite-bearing quartz similar to that occurring behind the townsite of Laverton. At Burtville itself the country is flat, with the exception of a few greenstone ridges at the north and south ends of the area examined and the broken edge of the granite tableland a few miles to the east. The greenstone ridges are most numerous towards the northern end of the district, but are mostly low, and at best occupy only a comparatively small area. In the neighbourhood of the townsite, and to the east, south-east, and south of it, the country for several miles is practically a dead level plain covered with a varying thickness of recent superficial deposits, and it is on this plain that most of the working shows are situated; the only breaks in it are in the neighbourhood of the Rock of Ages, Carib, and Mikado leases, where there are low ridges of greenstone and greenstone schist.

The rocks of this district consist of both greenstones and granites, the former being mostly massive and consisting of a hornblende series of the usual type, one specimen [6546] of which is, seen under microscopic examination, to be a holocrystalline rock, consisting essentially of hornblende and triclinic feldspar in about equal proportions, together with a little ilmenite, this latter being for the most part altered into leucoxene; the feldspars are mostly in the form of long prismatic crystals and are considerably clouded from the presence of alteration products; the hornblende is in large irregular flakes and lumps somewhat chloritised in parts, and consists of both tremolite and actinolite.

There appears to be a considerable development of schists near the junction of the greenstones with the granite, but owing to the cover of recent deposits which overlies the greater part of the district, the extent of these cannot be ascertained, and they can be seen outcropping only over one or two small areas, principally in the neighbourhood of the Carib lease. These greenstones are also traversed by one or two small belts of banded and hematite-bearing quartz; these, however, are usually of no length or continuity, the largest development of them is at the Rock of Ages and just to the east of the Carib.

The granitic rocks appear to be of two distinct ages, and consist of the main body forming the great sandy tableland commencing four or five miles east of the townsite and continuing easterly indefinitely; the western side of this tableland generally has more or less vertical cliff faces ("breakaways") (Photograph 6) rising 50

to 100 feet above the plain; the junction with the greenstones is usually half to one mile west from these breakaways, and appears to run on a general bearing slightly west of north and east of south.

The second body of granite is situated to the east of the townsite, and occupies a roughly circular area of about a mile in diameter; with the exception of one small area on the Maori Chief lease, it is entirely hidden beneath a varying depth of recent detrital deposits. From the scanty evidence available it would appear that this body of granite is intrusive into the greenstones which surround it on all sides, and it appears to have been subjected to the same stresses and strains as these rocks, the foliation, when such occurs, in the two classes being the same and the reefs generally parallel and sometimes continuous from one class to the other. A section of this granite shows it to be a biotite variety too much altered and weathered for satisfactory examination; the biotite, which is not very abundant, is in small flakes throughout the section, and is mostly altered to talc and a greenish chloritic material; the feldspars are in large crystals and plates, but are clouded and altered almost beyond recognition.

These granitic rocks are occasionally intersected by basic (dolerite?) dykes, which are met with in the workings and not being visible on the surface; one cut in the workings of the Prior Right, G.M.L. 1536, is said to have carried a little gold.

Considerable weathering and alteration has taken place both in these rocks and in the greenstones, and they are very soft and easily worked even for some distance below water level.

Several fairly extensive deposits of laterite (ironstone conglomerate) are found overlying the greenstone in places; one of these, a little to the east of G.M.L. 1423 (Eureka), though small, is apparently of very high grade.

It is within the area of granitic rocks that most of the payable quartz reefs are found, and it is in this respect that Burtville differs from most of the other known mining centres of Western Australia.

The quartz reefs are almost invariably small, but they make up for this by often being of exceptional richness; they are usually of clean white—sometimes blue—quartz, and generally vary from 6 to 12 inches in thickness, often extending longitudinally, however, for a considerable distance. They are fairly numerous both in the granitic area and in the greenstones, but throughout the greater part of the district, owing to the covering of recent detrital deposits, are seldom found outcropping; they are found by picking up "floaters" on the surface and subsequent deep costeening or sinking and cross-cutting across the supposed line of the reef, the soft nature and good standing quality of the country generally rendering the latter method the more satisfactory.

The occurrence of gold throughout the reefs is not regular, neither are the reefs themselves uniform in size, often pinching out to a mere thread and then making again into a body of stone 12 or 18 inches in thickness, these bunches usually being richer than the narrow parts of the reef, which are often almost free from gold; as a rule also, these bunches carry their size down vertically, the pinching being only lateral.

The richness of the reefs and the soft easily workable nature of the country render the district an ideal one for the prospector, but the reefs are too small to be of any value to large companies; a large number of them which are yielding good profits under present conditions, *i.e.*, above water and in soft country, will probably fail to do so when hard country is reached as, though the reefs appear likely to live to a considerable depth, the values are almost certain to drop considerably as soon as the hard settled country below water is reached, and in the case of many of the six-inch reefs at present worth two to three ounces, this fact is likely to prove fatal, for a six-inch two ounces reef in soft "auger" country is a very different thing to the same reef in hard, solid granite; however, as one or two of the reefs have already been worked to a depth of 150 feet without the country becoming uncomfortably hard, there is, at the worst, still a good length of life in front of mining the Burtville reefs.

The district as a whole is well watered, the supply being plentiful and of excellent quality except at the extreme south end, where it is unfit for drinking purposes.

Timber is still fairly plentiful, but consists only of Mulga, some of it, however, of very fair size.

The following is a brief description of the principal mines working, as they appeared at the time of my visit (Oct., 1904).

### The Mines.

WANDERER AND WANDERER SOUTH, G.M.Ls. 1011, 1413.—A good deal of work has been done on these leases and the workings were the deepest in the district, the main shaft being down 200 feet vertical with north and south drives at this level; these workings, however, were abandoned at the time of my visit and were inaccessible. The reef worked was of white quartz, and was said to have averaged about two feet and to have been very bunchy; the shoot of gold had an average width of about 50 feet and dipped at a fairly flat angle to the south; the gold is said to have given out altogether a few feet below water level, *i.e.*, at about 150 feet, though the reef itself is still going down strong in the lower levels.

At the date of my visit (October, 1905) a little prospecting work was being done near the north end of the reef; a shaft is here being sunk on the reef, which is about  $2\frac{1}{2}$  feet in thickness but of low grade; it is hoped in this shaft to pick up the continuation of a small rich shoot which had been worked on the surface. The reef is fairly



well defined, and can be followed on the surface through the two leases for a distance of 10 or 12 chains; it runs almost due north and south and dips at an angle of about 75 degrees to the east. The country is a fairly fine-grained massive greenstone, very soft and rotten down to water level, but getting hard and settled in the bottom of the old workings.

*Wanderer South, G.M.L. 1011.*

| Year.       | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|--------------|-----------------|---------------|
|             | tons.        | fine ozs.       | ozs.          |
| 1901 .. ..  | 180.00       | 410.89          | 2.27          |
| 1902 .. ..  | 207.75       | 419.35          | 2.01          |
| 1903 .. ..  | 420.90       | 938.47          | 2.22          |
| 1904 .. ..  | 242.00       | 93.38           | .38           |
| 1905 .. ..  | 72.00        | 58.10           | .80           |
| Total .. .. | 112.265      | 1,920.19        | 1.71          |

*Wanderer, G.M.L. 1413.*

| Year.      | Ore crushed. | Gold therefrom. | Rate per ton. |
|------------|--------------|-----------------|---------------|
|            | tons.        | fine ozs.       | ozs.          |
| 1904 .. .. | 65.00        | 69.91           | 1.07          |

TREBLE HANDED, G.M.L. 1634.—On this lease a good deal of work has been done on a small but exceptionally rich quartz leader running about north and south and dipping to the west at an angle of about 80 degrees. Several shafts have been put down on it, and the leader stoped out from the 150-foot level (water) to the surface for a considerable length; these workings were, however, inaccessible. The present owners are sinking a new main shaft with the intention of working the leader below water, they are now down 185 feet. The leader is said to have averaged not more than two inches, but to have been very regular and to have maintained its value well. The country is greenstone, and is very soft and rotten even at the bottom of the present main shaft. The water supply is fresh.

*Treble Handed, G.M.L. 1634T (1350T) (1108T).*

| Year.       | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|--------------|-----------------|---------------|
|             | tons.        | fine ozs.       | ozs.          |
| 1900 .. ..  | 7.00         | 44.67           | 6.38          |
| 1901 .. ..  | 27.00        | 93.57           | 3.47          |
| 1902 .. ..  | 35.50        | 233.04          | 6.56          |
| 1903 .. ..  | 65.50        | 531.90          | 8.12          |
| 1904 .. ..  | 29.00        | 68.20           | 2.35          |
| 1905 .. ..  | 21.00        | 61.17           | 2.91          |
| Total .. .. | 185.00       | 1,032.55        | 5.56          |

TEMPUS, G.M.L. 1068.—The main reef on this property runs about 5 degrees east of north and dips at a steep angle to the west ; it is of somewhat ironstained quartz and very irregular, having an average thickness of 6 to 8 inches, but often pinching out to a mere thread ; the larger makes of stone are not regular and frequently pinch out vertically as well as laterally ; in the bottom level it is fairly continuous and regular, varying from 6 to 8 inches, and appears to be going down well underfoot. The most irregular portion of the reef is close to the main shaft, where it is much broken, and for a short distance runs almost flat, and takes a fairly sharp turn to the westward for a short distance. A couple of chains south of the main shaft, a second reef comes in from the eastward and joins the main one. Not much work has been done on this, but as far as opened up it is exactly similar in character to the main one. There is no definite shoot of gold in the reef, the values being fairly regular ; the best stone was, however, obtained from the stopes above the bottom level below water, this stone yielded about 10ozs. per ton. The country is a fine-grained massive greenstone, but is very soft and decomposed even in the bottom workings.

Water was met with at 100 feet vertical depth, and is fresh and drinkable ; the supply is not very heavy, and comes in principally along the walls of the reef.

The principal workings consist of a main vertical shaft sunk to a depth of 160 feet, at which level drives have been put in along the reef for 160 feet south and 110 feet north, and the whole of this block stoped out to the surface, with the exception of the last 30 feet of the north drive, from which the stopes were only carried up 30 feet, when the reef cut out. Several underlay shafts have also been put down on the reef to water, and a little work has been done from them, but they are not in use now.

*Tempus, G.M.L. 1068.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1901  | .. | .. | .. | 180.00       | 769.07          | 4.26          |
| 1902  | .. | .. | .. | 132.50       | 495.83          | 3.74          |
| 1903  | .. | .. | .. | 235.00       | 611.99          | 2.60          |
| 1904  | .. | .. | .. | 270.00       | 364.75          | 1.35          |
| 1905  | .. | .. | .. | 170.00       | 1,000.76        | 5.88          |
| Total |    |    |    | 987.50       | 3242.40         | 3.28          |

NIL DESPERANDUM, G.M.L. 1044.—A considerable amount of scattered work has been done on this lease ; a number of shafts have been sunk near the north-east corner and a good deal of work done on a number of small quartz leaders, some of which were said to have been exceptionally rich ; these workings had, however, been abandoned and were inaccessible at the time of my visit. The

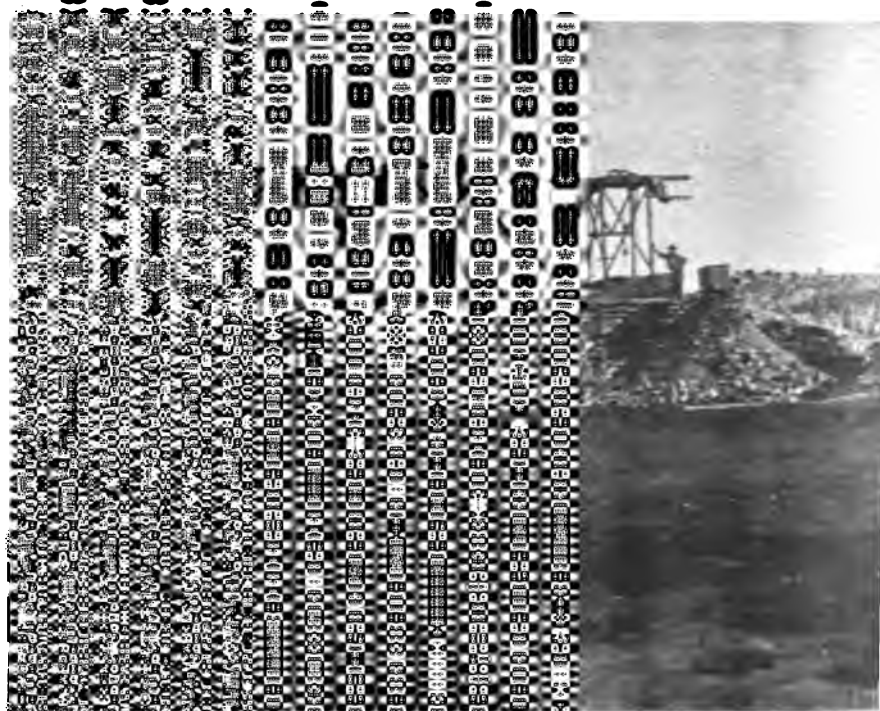
present workings are situated near the centre of the lease, and are on a small quartz reef running almost due north and south and dipping steeply to the west; on this a shaft has been sunk about 50 (1) feet, and drives put in 110 feet north and 40 feet south along the reef, and the whole of this block stoped out to within about 30 feet of the surface. The reef, as usual, is "bunchy," varying in thickness from a mere thread up to nearly two feet, the average being about 10 or 12 inches; the lenses vary, one being over 60 feet in length, and having an average thickness of nearly two feet, but carry their size well vertically; they pitch slightly towards the south. The footwall is very good and well defined, the hanging wall not being so regular, and it is the irregularities of this wall that cause the pinchings in the reef. A new main shaft is now being sunk to water level a chain or so north of the present workings, and a party of tributers are doing a little prospecting work about five chains farther north.

The country is a soft rotten granite, very easily worked and good standing ground.

*Nil Desperandum, G.M.L. 1044 (760).*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1897  | .. | .. | .. | 15.00        | 14.14           | .94           |
| 1899  | .. | .. | .. | 6.50         | 33.41           | 5.13          |
| 1900  | .. | .. | .. | 24.00        | 90.35           | 3.76          |
| 1901  | .. | .. | .. | 22.50        | 63.82           | 2.83          |
| 1902  | .. | .. | .. | 70.00        | 379.48          | 5.42          |
| 1903  | .. | .. | .. | 167.00       | 401.03          | 2.40          |
| 1904  | .. | .. | .. | 160.00       | 377.07          | 2.35          |
| 1905  | .. | .. | .. | 510.00       | 1,158.94        | 2.27          |
| Total | .. | .. | .. | 975.00       | 2,518.24        | 2.58          |

AWAY FROM HOME AND SAVAGE CAPTAIN, G.M.Ls. 1041, 1089.—  
(*Photograph 7*). These two leases are in the hands of the same owners, and are working on what is practically the one line of reef. Most work has been done on the Away from Home lease, where three makes of stone have been worked; these consist of separate parallel lenses, each looking northward, lying to the westward of the other, the southern end of one block apparently lying directly across from the northern end of the other, and may be different reefs or may be the same reef faulted over, there not being sufficient work done on any of them to definitely decide this point; it is more probable, however, that they are separate parallel reefs. The most southern block appears to have been worked right out, and was abandoned. On the next block the present working shaft is down 100 feet, and a drive 50 feet in length has been put in at this level, and a block 20 feet high stoped out along its whole length; a block 15 to 20 feet long has also been stoped out from the 50 feet level



Govt. Photo. Litro.

artville.



to the surface. On the next make of stone the shaft is down 100 feet, and 50 feet to 60 feet of driving have been done at this level, but little or no stoping. On the northern shoot, which is on the Savage Captain lease, the main vertical shaft is down 140 feet. At the 100 foot level, a block of stone 130 feet in length has been stoped out, north of the shaft, up to the 100 foot level, and the level continued another 40 feet north, while it has also been carried 65 feet south of the shaft. Water level in these workings is 100 feet, and bailing is being carried on from the bottom level at the rate of about 1,200 gallons per day, the water being fresh. The size of these shoots varies from a few inches up to a little over two feet; they underlie steeply to the west and pitch slightly to the south; the quartz is clear and white and somewhat glassy in places. The country rock is granite, and is very soft and easily worked down to water level, but below this in the northern workings it is commencing to get very hard and settled.

*Away from Home Leases, G.M.Ls. 1041, 1087.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1900  | .. | .. | .. | 45.00        | 432.13          | 9.60          |
| 1901  | .. | .. | .. | 279.50       | 1,177.09        | .42           |
| 1902  | .. | .. | .. | 31.00        | 59.11           | 1.90          |
| 1903  | .. | .. | .. | 215.00       | 229.65          | 1.06          |
| 1904  | .. | .. | .. | 386.00       | 966.20          | 2.50          |
| 1905  | .. | .. | .. | 461.00       | 656.58          | 1.42          |
| Total |    |    |    | 1417.50      | 3520.76         | 2.48          |

*Savage Captain, G.M.L. 1089.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1901  | .. | .. | .. | 84.00        | 282.25          | 3.36          |
| 1902  | .. | .. | .. | 134.00       | 440.51          | 3.28          |
| 1903  | .. | .. | .. | 394.70       | 1,598.90        | 4.05          |
| 1904  | .. | .. | .. | 494.50       | 1,340.82        | 2.71          |
| 1905  | .. | .. | .. | 408.00       | 1,043.55        | 2.30          |
| Total |    |    |    | 1515.20      | 4706.03         | 3.10          |

MAORI CHIEF, G.M.L. 1048.—The main workings on this property are at a depth of 180 feet; this being the greatest depth to which work has been carried within the granite area. Some very rich stone is said to have been taken out of these workings, but they had been abandoned owing to the decreased values of the reef in the hard country in the bottom workings. The workings were flooded, and were, therefore, inaccessible at the time of my

visit ; the country was soft and easily worked to water, but below this began to get very hard, and in the bottom workings consists of a very hard compact massive granite.

At present a little prospecting work is being done at the south end of the block, and a shaft is being sunk with the hope of picking up a second rich shoot ; this shaft, however, was only down about ten feet at the time of my visit, and had not got through the surface capping of recent deposits.

These are the only workings down into the hard settled country in the granite area, and the fact that the gold values become too poor to pay in this hard country, though not conclusive, is certainly a point against the long life of the Burtville reefs.

*Maori Chief, G.M.L. 1048.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1900  | .. | .. | .. | 24.00        | 116.75          | 4.86          |
| 1901  | .. | .. | .. | 50.00        | 261.69          | 5.23          |
| 1903  | .. | .. | .. | 99.60        | 676.52          | 6.79          |
| 1904  | .. | .. | .. | 88.00        | 257.30          | 2.92          |
| 1905  | .. | .. | .. | 73.00        | 372.22          | 5.10          |
| Total | .. | .. | .. | 334.60       | 1684.48         | 5.03          |

PRIOR RIGHT, G.M.L. 1536.—The original workings on this block were at the north end of it on a small quartz leader running nearly due north and south and dipping at an angle of about 80 degrees to the west ; this leader has been worked out to a depth of about 80 feet to the point at which it was cut off by a basic dyke, which runs about north-west and dips south-west across the leader at a comparatively flat angle.

This dyke has weathered into a soft reddish "pug," which is said to carry a little gold over its full thickness, about fourteen feet. while its values in close proximity to the point at which it is struck by the leader are said to have been pretty high ; so far no attempts have been made to work this dyke, as owing to its "puggy" nature it is not amenable to ordinary battery and leaching treatment. The main leader is said to have been from 1 to 3 inches in thickness, and to have carried very high values ; it is faulted off at the south end and has been worked completely out above the dyke, but no efforts were made to pick it up below ; the workings on it were abandoned and were inaccessible. At the time of my visit a little work of a prospecting nature was being done some three chains to the east of the old workings, where a shaft had been put down about 50 feet, and had cut through the dyke ; a couple of small leaders were cut in this but they were not good enough to pay. There are a number of small leaders through the lease, but they are mostly too small or too poor. The country is a very much weathered granite, and is very soft and easily worked.

During 1905, this lease crushed 14.00 tons of ore for a yield of 5.09 fine ounces; being at the rate of .36 ozs. per ton.

**GOLDEN BELL, G.M.L. 1553.**—The reef on this property is about the best defined and most continuous of those so far worked within the granite area; it runs almost due north and south, dipping at an angle of about 60 degrees to the west, and has been proved for a length of over 20 chains. Like all the reefs in the district, it is lenticular and "bunchy," varying in size from a mere thread in places up to as much as two and two and a-half feet, and averaging about 10 inches right through; the lenses of stone vary in length from 20 to 50 feet, and run pretty well vertically and carry their size down well; the stone is fairly uniform in its gold contents throughout the whole length of the workings, and, if anything, is slightly better at water level, where it also carries a fair percentage of pyrites. The walls of the reef are clean and well defined; the country is a very soft decomposed granite, very easily worked, and standing well, and is still soft in the lowest workings (water level). Water was met with at 100 feet, and is fresh and drinkable. Near the south end of the lease, the reef appears to have been cut off by a large fault running north-east and south-west, and no traces of it have been picked up south of this.

A good deal of work has been done on this block, and several shafts have been sunk to water level; from the presnet working shaft, about 220 feet of driving has been done north and 30 feet south at the 120 feet (U.L.) level—100 feet vertical; stoping has been carried along the whole length of the north level to within about 30 feet of the surface, no stoping has been done to the south. In addition to these workings, a small party of tributaries are sinking a prospecting shaft somewhat nearer the southern boundary.

On the adjoining block to the north (the Golden Bell North, G.M.L. 1566), a good deal of work has also been done on the same reef down to water level. In these workings it has exactly the same characteristics as in the Golden Bell lease, and averages about the same size.

*Table showing the Yield of the Golden Bell Reef.*

| Year. | Name and Number of Lease.           | Ore crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|-------------------------------------|--------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                     |              |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                     | tons.        | fine ozs.       | ozs.          | tons.        | fine ozs.       | ozs.                  |
| 1904  | Golden Bell, G.M.L. 1553r ...       | 48.00        | 223.52          | 4.65          |              |                 |                       |
| 1905  | Do. do. ...                         | 930.50       | 3,342.66        | 3.59          |              |                 |                       |
|       |                                     |              |                 |               | 978.50       | 3,566.18        | 3.64                  |
| 1904  | Golden Bell North, G.M.L. 1566r ... | 92.50        | 341.83          | 3.59          |              |                 |                       |
| 1905  | Do. do. ...                         | 232.75       | 367.5           | 1.58          |              |                 |                       |
|       |                                     |              |                 |               | 325.25       | 709.33          | 2.15                  |
|       | Total ...                           | ...          | ...             | ...           | 1,303.75     | 4,275.76        | 3.29                  |



**CREMORNE, G.M.L. 1592 (1494).**—This property is situated about half-a-mile north-east of the Golden Bell, and on it a large amount of work has been done in the past, on a quartz reef running north and south and dipping to the west. This reef appears to be on the junction of the granite with the greenstones; there are no outcrops, the whole locality being covered with a considerable thickness of recent deposits, and the stone in the dumps is too rotten and decomposed to form any definite conclusion as to what it has been, but the north end of the reef appears to be in greenstone, while the south is in granite. The reef is said to have been larger and the average to have yielded some very rich stone. There was a ten-head battery on this lease at one time, but it was removed about eighteen months ago; this being the only lease in this district besides the Sons of Westralia on which a battery has been erected.

*Cremorne, G.M.L. 1592 (1494), (1034).*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine oz.        | ozs.          |
| 1900  | .. | .. | .. | 70.00        | 228.61          | 3.26          |
| 1901  | .. | .. | .. | 58.50        | 108.11          | 1.84          |
| 1904  | .. | .. | .. | 52.50        | 34.58           | .65           |
| 1905  | .. | .. | .. | 7.00         | 10.49           | 1.50          |
| Total | .. | .. | .. | 188.00       | 381.79          | 2.04          |

**MAXIM, G.M.L. 1384.**—This property is situated about a mile and a-half north-east of Burtville townsite, and is outside the granitic area; the country rock being a fairly fine-grained massive greenstone very much decomposed. The reef runs a little north of north-west, and dips to the west; it is traceable for about twenty chains, and appears to have been considerably larger than those in the granite. Several shafts have been sunk, and a good deal of work has been done on the property, but it was lying idle at the time of my visit. Up to the end of 1905 164.90 tons of stone had been crushed from this lease for a yield of 141.81 fine ozs., being at the rate of .86ozs. per ton.

**THE BROTHERS, G.M.L. 1054.**—The workings on this lease are also situated in greenstone country, but the reef is small and has exactly the same characteristics as those in the granite, consisting of a series of lenses of varying length, all pitching to the south at a fairly sharp angle; these lenses are generally connected by a small vein of quartz, but often there is only a "face"; they vary a good deal in size, those at the south end of the workings being almost two feet in one or two places, though the average size is about eight inches. The general trend of the reef is eight degrees east of north, and it has a dip of about 75 degrees to the west; at the south end there is a second parallel leader about 14 feet to the west, this however, being

only a short length ; both reefs are crossed by a third small east and west leader which yielded small pockets of rich stone at its junction with the others, and in the part of it between them. The country in proximity to the reef is a very soft rotten greenstone schist, foliated parallel to the strike of the reef, but turning into a massive variety 20 to 30 feet to the west of it. It seems not unreasonable to presume that, if a little more cross-cutting was done across this belt of schists, other makes of stone parallel to the present line would be picked up.

A good deal of work has been done on the lease, and a number of shafts have been sunk to water (70ft. v.d.) between which level and the surface a block 400 feet in length has been worked out. The present owners are now working below water level, and have got their main shaft down 140 feet ; a drive has been put in south along the reef at the 125 feet level for a distance of 140 feet, but little or no stoping has been done ; the shoot of gold worked in the upper levels is dipping slightly south, and this bottom level is being pushed on to pick it up ; so far the values in it are not too good.

The water comes in principally along the footwall of the reef and also very strongly along a fault some 12 to 15 feet to the west of the reef ; it is somewhat brackish but is good stock water.

*The Brothers, G.M.L. 1054.*

| Year.         | Ore crushed. | Gold therefrom. | Rate per ton. |
|---------------|--------------|-----------------|---------------|
|               | tons.        | fine ozs.       | ozs.          |
| 1900 .. .. .  | 28.00        | 73.89           | 2.64          |
| 1901 .. .. .  | 82.00        | 292.37          | 3.56          |
| 1902 .. .. .  | 260.50       | 342.75          | 1.31          |
| 1903 .. .. .  | 108.00       | 156.83          | 1.45          |
| 1904 .. .. .  | 13.00        | 6.66            | .51           |
| 1905 .. .. .  | 24.00        | 50.55           | 2.10          |
| Total .. .. . | 515.50       | 923.05          | 1.79          |

MYSTERY, G.M.L. 1664 (1563).—On this lease a good deal of work has been done on a small quartz reef which runs north and south, and dips at a fairly steep angle to the westward. This reef consists of a series of small irregular lenses of stone varying up to 30 feet in length, and having an average thickness of about 8 inches ; these lenses have a decided pitch to the north but do not carry their size too well ; the distance between them varies, but their is generally a small vein of quartz connecting them. The country rock is a greenstone schist, very soft and rotten but a good deal of siliceous ironstone occurs on the footwall, mostly in irregular bunches, and is very hard and compact and, so far, practically free from gold.

Water was struck at a vertical depth of 70 feet, and is salt. Several underlay shafts have been sunk to water (90 feet U.L.), and a good deal of irregular disconnected work has been done on the reef both on this lease and on the adjoining one on the north.

*Mystery, G.M.L. 1664 (1563).*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs        | ozs.          |
| 1904  | .. | .. | .. | 126.00       | 193.83          | 1.53          |
| 1905  | .. | .. | .. | 28.00        | 25.38           | .70           |
| Total |    |    |    | 154.00       | 219.21          | 1.42          |

KARRIDALE, G.M.L. 1010.—Two lines of reef have been worked on this property, but most of the work has been done on the southern one which is by far the richest; and also the more regular. The northern reef, which runs on a bearing of 240 degrees and dips at a fairly flat angle to the north-west, is very irregular in size, varying, within a few feet, from a few inches up to two or three feet in thickness; the shoot of gold worked is said to have been about 50 feet in length and to have cut out at a depth of 60 feet. Work is now proceeding on this reef at a depth of 70 feet, where a drive is now being put in southerly along the reef in the hopes of picking up another shoot. The reef at the south end runs on a bearing of 220 degrees, and dips at an angle of about 60 degrees to the north-west; it is a little more regular than the other, but is smaller, its average size being about twelve inches, getting smaller towards the southern end. Two shoots of gold have been worked; the northern shoot was about 90 feet long at water level, and ran out to a point a few feet below the surface; the reef in this was bigger than usual, being from two to three feet six in one place—near the surface; these big makes of stone were not much good right through, the best values being obtained on the footwall side, the reef is smaller and more regular along the bottom level, being from 8 to 12 inches. The southern shoot, which is the one being worked at present, is about 100 feet in length at water level, and tapers to a point at the surface the same as the other; it has been worked out to within about 30 feet of the surface, and the best stone was got along water level; the stone is much smaller in this shoot, being from 1 to 12 inches, the lenses or "makes" of stone being very irregular; the footwall is clean and regular, the bunches being caused by irregularities, principally in the hanging wall; the reef appears to be going down well under foot at the water level, where it also carries a considerable percentage of pyrites. As the two shoots are only separated by a few feet of blank stone at water level, and are making towards each other, there should be a good length of pay ore when the next level is opened up. The country is greenstone schist, very much weathered and decomposed; the reefs run and dip with the foliation of the schists; on the footwall of the reef, these schists have been very highly altered over a width of four to six feet, and converted into a band of siliceous ironstone, mostly very hard and compact, locally known as "jasper"; this band occasionally carries little gold, but not sufficient to make it payable.

A second of these bars runs on a north-westerly bearing across about the centre of the lease, probably marking an old line of fault, which, on the surface, appears to have cut off the southern reef, and it may be that the northern one is merely the extension of this reef faulted over. Water was struck in the workings at about 80 feet (v.d.) and is salt.

The extension of the southern reef is also being worked on the north end of the adjoining block on the south (the Castlereagh, G.M.L. 1598) where a good deal of work has been done on it to water level.

*Karridale, G.M.L. 1010.*

| Year.       |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|----|----|----|--------------|-----------------|---------------|
|             |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1900        | .. | .. | .. | 59.00        | 241.02          | 4.08          |
| 1901        | .. | .. | .. | 143.00       | 398.35          | 2.78          |
| 1902        | .. | .. | .. | 166.00       | 387.33          | 2.33          |
| 1903        | .. | .. | .. | 687.33       | 711.93          | 1.03          |
| 1904        | .. | .. | .. | 282.25       | 1,000.25        | 3.54          |
| 1905        | .. | .. | .. | 291.00       | 2,143.71        | 7.36          |
| Total .. .. |    |    |    | 1,628.58     | 4,892.59        | 2.99          |

BOND'S FIND, G.M.L. 1019.—All the work on this lease has been done at the north end on a small irregular quartz reef striking about north-north-east, and dipping at a very flat angle to the westward. A number of shafts have been sunk on this reef to depths varying from 40 to 75 feet, and a good deal of irregular and disconnected work has been done on it. The reef dips westerly at an angle of about 15 degrees, but turns over sharply and forms several sharp sigmoidal curves northerly, and, altogether, is very irregular and broken. The size of the reef varies considerably, the average being only a few inches, though bunches up to 18 inches have been worked, whilst again it will pinch into a mere thread for some distance. The length of the shoot of gold worked was about 200 feet, but the stone was not quite uniform over this length, some of it being very good whilst some was rather poor. The country is decomposed greenstone, and appears to be intruded by several greenstone dykes, though it is so rotten and weathered that it is almost impossible to definitely recognise the presence of these. ||

No work has been done below water level (75 feet v.d.). || || ||

A similar class of reef to this has been worked on the adjoining lease to the east, the Roscommon.

*Bond's Find. G.M.L. 1019.*

| Year.        | Ore crushed. | Gold therefrom. | Rate per ton. |
|--------------|--------------|-----------------|---------------|
|              | tons.        | fine ozs.       | ozs.          |
| 1899 .. .. . | 11.50        | 34.04           | 2.96          |
| 1900 .. .. . | 47.50        | 112.62          | 2.37          |
| 1901 .. .. . | 123.00       | 342.84          | 2.78          |
| 1902 .. .. . | 129.00       | 500.67          | 3.88          |
| 1903 .. .. . | 278.00       | 377.83          | 1.35          |
| 1904 .. .. . | 194.00       | 219.84          | 1.13          |
| 1905 .. .. . | 285.00       | 344.29          | 1.20          |
| Total .. ..  | 1,068.00     | 1,932.13        | 1.81          |

ROCK OF AGES, G.M.L. 1338.—Two or three fair sized hematite-bearing quartz lodes run through this lease on a bearing of 186 degrees, dipping at an angle of about 75 degrees to the west; along the hanging wall of the best defined of these, runs a small white quartz reef, on which a fair amount of work has been done down to water level. The reef is somewhat irregular, but it was impossible to see much owing to most of the block having been stoped out and to no development work being done; it is said to have averaged about two feet, but is, however, very small in the north face. The country is very soft, and consists of a decomposed, somewhat schistose greenstone; water was struck at 130 feet, and is said to be fresh and drinkable. The property was idle at the time of my visit.

*Rock of Ages. G.M.L. 1338.*

| Year.        | Ore crushed. | Gold therefrom. | Rate per ton. |
|--------------|--------------|-----------------|---------------|
|              | ton.         | fine ozs.       | ozs.          |
| 1902 .. .. . | 49.00        | 151.30          | 3.08          |
| 1903 .. .. . | 293.50       | 713.49          | 2.09          |
| 1904 .. .. . | 224.00       | 299.94          | 1.33          |
| 1905 .. .. . | —            | —               | —             |
| Total .. ..  | 566.50       | 1,164.73        | 2.05          |

SONS OF WESTRALIA, G.M.L. 934.—This property is situated a little over four miles to the south of Burtville townsite. The workings are on a fair-sized quartz reef, which runs on a bearing a little east of north, and dips at a fairly steep angle to the westward; this reef is said to have been from three to five feet in thickness all through the workings, and to have carried good values right through. It has been worked to a depth of 140 feet (v.d.); from the 100 feet level to the surface, a block from 400 to 500 feet in length has been stoped out, and at 140 feet about 150 feet of driving has been done on the reef, but no stoping. The reef is said to have averaged about four feet along this drive, but owing to the workings being flooded I was able to make an examination of them. Near the surface in one

place the reef is about four feet thick, and has good clean walls, the footwall being especially good; a little chloropal (a silicate of iron) is associated with the quartz near the surface on this wall, giving it a characteristic green colour, and is also found on the wall itself.

The country is greenstone, very soft and rotten, as far as opened up. Water was met with at 100 feet, but is salt.

*Sons of Westralia, G.M.L. 934.*

| Year.       | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|--------------|-----------------|---------------|
|             | ton.         | fine ozs.       | ozs.          |
| 1899 .. ..  | 35.00        | 187.50          | 5.35          |
| 1900 .. ..  | 90.00        | 669.70          | 7.44          |
| 1901 .. ..  | 243.00       | 665.78          | 2.74          |
| 1902 .. ..  | 748.00       | 1,826.39        | 2.44          |
| 1903 .. ..  | 103.00       | 422.61          | 4.10          |
| 1904 .. ..  | 130.00       | 143.73          | 1.10          |
| 1905 .. ..  | —            | —               | —             |
| Total .. .. | 1,349.00     | 3,915.71        | 2.90          |

MIKADO, G.M.L. 943.—The accompanying plans show the amount of work which has been done on this lease. Several lines of reef are being worked, but the majority of the work has been done on what is known as the Mikado reef. This reef can be traced on the surface in a roughly north-north-easterly and south-south-westerly direction for a distance of about 20 chains, the outcrop towards the south end being 8 to 10 feet in thickness, and very continuous; in the workings—which are to the north of the big outcrop, which is apparently no good—it is very irregular, varying in a short distance from a solid body of quartz two to three feet thick, to a string of mere threads, these, in turn, sometimes cutting out almost entirely, and at other times making again into a fairly solid body; there are a number of small leaders on both sides of the main line, these are mostly very small and consist of a series of irregular lenses with narrow threads of quartz connecting them; they are very small as a rule, and often only extend for a few feet, and are often run much flatter than the main line, and run into it. At the 110 feet level, three lines of reef have been opened up, but insufficient work has been done on two of them to get an accurate idea of their extent or relationship. A little to the north of the main shaft an east and west fault dipping to the south cuts across the reef, which is thrown about six feet to the east and very much broken. This fault is evidently the continuation of the shear line seen on the surface near the north-east corner of the lease, and marked on the surface by a fair-sized hematite-bearing quartz lode. The workings were only accessible to the 110 feet level, being full of water below this; the country is very soft and easy to work and shows no signs of becoming hard even at the 140 feet level; it consists of greenstone schists, the foliation running slightly east of north, and dipping

steeply west, and it is parallel to these lines of foliation that the reef occurs. A fairly good supply of water was struck at 110 feet, but it is salt; it is, however, being used for boiler purposes with satisfactory results.

*Mikado, G.M.L. 94?*

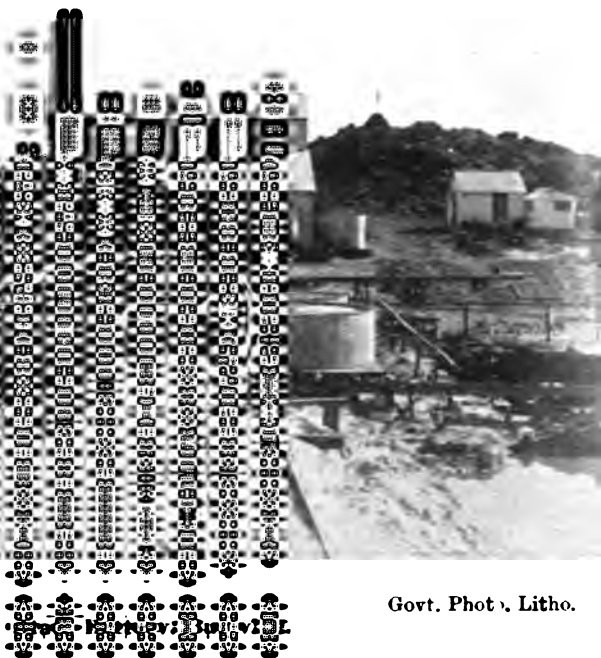
| Year.        | Ore crushed. | Gold therefrom. | Rate per ton. |
|--------------|--------------|-----------------|---------------|
|              | tons.        | fine ozs.       | ozs.          |
| 1900 .. .. . | 62.00        | 38.93           | .63           |
| 1902 .. .. . | 145.00       | 90.45           | .62           |
| 1903 .. .. . | 135.00       | 76.76           | .57           |
| 1904 .. .. . | 60.00        | 42.00           | .70           |
| 1905 .. .. . | 622.50       | 648.79          | 1.04          |
| Total .. ..  | 1,024.50     | 886.93          | .66           |

STATE BATTERY.—A State Battery (*Photograph 8*) has been erected at Burtville, and since starting operations in October, 1903, the mill has crushed, up to the close of 1905, 10,869 tons of ore, yielding 27,907ozs. of gold, or an average of a little over 2½ozs. for every ton crushed.

The following Table, compiled from the official statistics, shows the total gold returns from the leases at Burtville up to the end of 1905:—

| Name and Number of Lease.                         | Ore crushed. | Gold therefrom. | Rate per ton. |
|---------------------------------------------------|--------------|-----------------|---------------|
|                                                   | tons.        | fine ozs.       | ozs.          |
| Away from Home Lease, G.M.L. 1041r, 1087r .. .. . | 1,417.50     | 3,520.76        | 2.48          |
| Banker, G.M.L. 1397r .. .. .                      | 229.50       | 349.80          | 1.52          |
| Baron Olive, G.M.L. 1100r .. .. .                 | 89.00        | 126.38          | 1.42          |
| Black Swan, G.M.L. 940r .. .. .                   | 1,310.50     | 1,731.37        | 1.32          |
| Black Swan Proprietary, G.M.L. 940r }             |              |                 |               |
| Bond's Find, G.M.L. 1019r .. .. .                 | 1,068.00     | 1,932.13        | 1.81          |
| Brothers, G.M.L. 1054r .. .. .                    | 515.50       | 923.05          | 1.79          |
| Blue Moon, G.M.L. 1666r .. .. .                   | 17.00        | 33.73           | 1.98          |
| Castlereagh, 1598 .. .. .                         | 25.00        | 40.06           | 1.60          |
| Carib, G.M.L. 944r .. .. .                        | 497.00       | 460.99          | .92           |
| Climax, G.M.L. 1369r .. .. .                      | 8.00         | 2.47            | .31           |
| Cremorne, G.M.L. 1592r (1494r) .. .. .            | 188.00       | 381.79          | 2.04          |
| Edinboro' Castle, G.M.L. 271r .. .. .             | 210.00       | 503.61          | 2.39          |
| Edinboro' Castle, G.M.L. 811r .. .. .             | 478.00       | 911.02          | 1.91          |
| Edinboro' Castle North, G.M.L. 1012r .. .. .      | 136.00       | 204.88          | 1.50          |
| Edinboro' Castle South, G.M.L. 809r .. .. .       | 31.00        | 166.10          | 5.35          |
| Edith Hope, G.M.L. 841r .. .. .                   | 565.00       | 301.75          | .53           |
| Eldorado, G.M.L. 1112r .. .. .                    | 47.25        | 43.42           | .91           |
| Eureka, G.M.L. 1423r .. .. .                      | 14.25        | 5.18            | .36           |
| Exchequer, G.M.L. 1345r .. .. .                   | 343.00       | 109.64          | .32           |
| Enterprise, G.M.L. 1551r .. .. .                  | 96.00        | 36.78           | .38           |
| Floater, G.M.L. 1234r .. .. .                     | ..           | * 3.44          | ..            |
| Fortunatus, G.M.L. 1493r .. .. .                  | 4.50         | 2.84            | .63           |
| Golden Bell, G.M.L. 1553r .. .. .                 | 978.50       | 3,566.18        | 3.64          |
| Golden Bell North, G.M.L. 1566r .. .. .           | 325.25       | 709.58          | 2.15          |
| Golden Flat, G.M.L. 1104r .. .. .                 | 50.65        | 191.03          | 3.77          |
| Golden Fleece, G.M.L. 1164r .. .. .               | 44.00        | 30.42           | .69           |
| Golden Orbit, G.M.L. 1398r .. .. .                | 1,188.50     | 2,192.75        | 1.84          |
| Golden Ring, G.M.L. 801r .. .. .                  |              |                 |               |

\* Specimens.



Govt. Phot. Litho.





| Name and Number of Lease.                | Ore<br>crushed.  | Gold<br>therefrom. | Rate<br>per ton. |
|------------------------------------------|------------------|--------------------|------------------|
|                                          | tons.            | fine ozs.          | ozs.             |
| Golden Ring East, G.M.L. 1037r           | 12.75            | 24.57              | 1.92             |
| Gabberwock, G.M.L. 1457r                 | 13.00            | 38.47              | 2.96             |
| Hard Lump, G.M.L. 1411r                  | 25.00            | 28.03              | 1.12             |
| Independence, G.M.L. 1293r               | 12.00            | 7.95               | .66              |
| Karridale South, G.M.L. 1400r            | 13.00            | 11.81              | .91              |
| Karridale, G.M.L. 1010r                  | 1,628.58         | 4,882.59           | 2.99             |
| Killarney, G.M.L. 1287r (1062r)          | 46.00            | 36.04              | .79              |
| Lady Kate, G.M.L. 1261r                  | 12.00            | 11.81              | .98              |
| Lady Myrtle, G.M.L. 1609r                | 70.00            | 57.94              | .82              |
| Leviathan, G.M.L. 944r, etc.             | 203.75           | 83.39              | .40              |
| Maori Chief, G.M.L. 1048r                | 334.60           | 1,684.48           | 5.03             |
| Maori Chief Extended, G.M.L. 1114r       | 118.00           | 506.49             | 4.29             |
| Marion, G.M.L. 1647r                     | 12.00            | 4.67               | .39              |
| Maxim, G.M.L. 1384r                      | 164.90           | 141.81             | .86              |
| Maxim North, G.M.L. 1404r                | 15.05            | 9.06               | .60              |
| Meantime, G.M.L. 1635r                   | 7.00             | 10.49              | 1.49             |
| Merry Pilgrim, G.M.L. 1314r              | 81.00            | 86.48              | 1.07             |
| Mikado, G.M.L. 943r                      | 1,024.50         | 896.93             | .86              |
| Mo i Ani, G.M.L. 1434r                   | 128.00           | 311.59             | 2.43             |
| Mount Brown, G.M.L. 1265r                | 31.50            | 25.70              | .81              |
| Mount Weld, G.M.L. 673r                  | 67.00            | 31.08              | .46              |
| Mount Weld Consols, G.M.L. 1105r         | 265.50           | 117.06             | .44              |
| Mount Wilga Proprietary, G.M.L. 833r     | 296.00           | 412.25             | 1.39             |
| Mystery, G.M.L. 1664r (1563r)            | 154.00           | 219.21             | 1.42             |
| Nā Desperandum, G.M.L. 1044r             | 975.00           | 2,518.24           | 2.58             |
| Nā Desperandum North, G.M.L. 1286r       | 134.30           | 348.06             | 2.59             |
| Nonpareil, G.M.L. 1436r                  | 22.00            | 22.10              | 1.00             |
| Oldfield, G.M.L. 1292r                   | 76.40            | 156.27             | 2.04             |
| Ophir, G.M.L. 1217r                      | 41.00            | 24.61              | .60              |
| Ophir No. 2, G.M.L. 1389r                | 60.35            | 42.68              | .70              |
| Pluck Up, G.M.L. 1307r                   | 13.50            | 20.39              | 1.51             |
| Prior Right, G.M.L. 1536r                | 14.00            | 5.09               | .36              |
| Queen of Hearts, G.M.L. 1317r            | 15.00            | 26.08              | 1.66             |
| Queen of the North Extended, G.M.L. 478r | 60.00            | 139.11             | 2.32             |
| Red Rover, G.M.L. 1331r                  | 30.50            | 11.62              | .38              |
| Riddle, G.M.L. 1057r                     | 378.25           | 852.49             | 2.25             |
| Rise Again, G.M.L. 1337r                 | 8.40             | 10.90              | 1.29             |
| Rock of Ages, G.M.L. 1338r               | 566.50           | 1,164.73           | 2.05             |
| Roscommon, G.M.L. 1417r                  | 577.00           | 377.80             | .65              |
| Sailor Prince, G.M.L. 781r               | 3,891.00         | 4,408.15           | 1.13             |
| Sailor Prince No. 1 South, G.M.L. 852r   | 64.00            | 32.21              | .50              |
| Savage Captain, G.M.L. 1089r             | 1,515.20         | 4,706.03           | 3.10             |
| Silistree, G.M.L. 1631r                  | 12.00            | 5.10               | .42              |
| Sons of Westralia, G.M.L. 934r           | 1,349.00         | 3,915.71           | 2.90             |
| Surprise, G.M.L. 1461r (853r)            | 72.00            | 203.28             | 2.82             |
| Tattersalls, G.M.L. 1668r                | 5.00             | 10.24              | 2.05             |
| Tempus, G.M.L. 1068r                     | 987.50           | 3,242.40           | 3.28             |
| Third Attempt, G.M.L. 1169r              | 8.00             | 7.37               | .92              |
| Tired Feeling, G.M.L. 1024r              | 125.00           | 166.89             | 1.33             |
| Tower Hill, G.M.L. 1325r                 | 8.00             | 10.62              | 1.33             |
| Treble Handed, G.M.L. 1634r (1350r)      | 185.00           | 1,032.55           | 5.58             |
| True Blue, G.M.L. 1464r                  | 83.00            | 147.41             | 1.77             |
| Try Again South, G.M.L. 1412r            | 33.00            | 156.69             | 4.74             |
| Turn Over, G.M.L. 1466r                  | 36.55            | 17.83              | .48              |
| Wanderer, G.M.L. 1011r                   | 1,122.65         | 1,920.19           | 1.71             |
| Wanderer South, G.M.L. 1413r             | 65.00            | 69.91              | 1.07             |
| Walhine, G.M.L. 1116r                    | 10.50            | 11.13              | 1.06             |
| Wee Macgregor, G.M.L. 1605r              | 18.00            | 36.28              | 2.01             |
| Sundry Claims                            | 541.65           | 426.50             | .78              |
| At Burtville State Battery               | 17.00            | * 896.33           | —                |
| Burtville Cyanide Works                  | ..               | † 1,551.29         | ..               |
| Burtville Ore Reduction Works            | ..               | † 949.53           | ..               |
| Trig Hill Battery                        | ..               | ..                 | ..               |
| <b>Total</b>                             | <b>29,534.28</b> | <b>57,764.18</b>   |                  |

\* Includes 888.73 ozs. by cyanide.

† By cyanide.

## **Erlistoun District.**

The road from Laverton to Duketon for the first twelve miles passes over plains covered with recent deposits and broken here and there by outcrops of low greenstone ridges, and then over a couple of miles of granite similar to that at Mount Crawford, afterwards over loam flats and sand plains to a point about two miles beyond the Cork Tree Hotel, where the granite again outcrops, having been apparently continuous the whole way, beneath the sand plains. This granite occupies the country for about another six miles, when it gives place to greenstones of the usual type, traversed by several very persistent bands of hematite-bearing quartz, and extending on past Mount Varden and on towards Erlistoun and Duketon. This area of granite appears to be different from the main body farther east, and though it is probably part of that to the west of Baneygo, it is similar to that of Crawford, and appears to be newer than and intrusive into the greenstones.

The greenstones of the Mount Varden belt occupy a very considerable area, having a width known to exceed 10 to 12 miles, and extending northerly as far as Duketon; a considerable portion of this area is, however, hidden beneath a great thickness of recent detrital deposits; the mining centres of Mount Varden (King of Creation and Little Doris), Kirkpatrick's, Erlistoun (Mistake), and Baneygo are all situated on this belt, Duketon appearing to be about the north-western limit of it. The eastern boundary of the belt is the large body of granite which lies some four miles east of Mount Varden, and apparently runs continuously from Burtville on northerly past Duketon; the western boundary is not known from actual personal observation, but near the north end it is formed by a belt of granite lying some half dozen miles west of Baneygo, and apparently continuous with that crossing the road between Crawford's Well and Cork Tree.

### **Mount Varden.**

The district officially known as Mount Varden lies about 36 miles to the north of Laverton; as before stated, the rocks comprising the auriferous area consist of greenstones of the usual type traversed by several very persistent parallel bands of hematite-bearing quartz, and here, having a width of about ten miles, they are mostly of a massive and foliated variety, and are considerably weathered and decomposed. Three main lines of hematite-bearing quartz lodes traverse these greenstones running on a bearing about 15 degrees west of north; these are very persistent and can be traced across country for several miles, usually in the form of low rough ridges and isolated hills, often of considerable height.

The most easterly of these lines is the one of which Mount Varden forms the highest point; this belt is several chains in width,



Govt. Photo. Litho.





Govt. Photo. Litho.



and consists of altered greenstone schist and hematite-bearing quartz, being very similar to the belt at Cock of the North, Laverton; it runs on a bearing of about 243 degrees, dipping steeply to the west, and can be followed both north and south for several miles; several fair sized lenticular reefs are associated with it, and one or two of these are being worked with fairly satisfactory results. The second, or middle line, is about two miles to the west of this one, the highest point on it forming the hill known as Nolan's Trig. (22); it runs on a bearing about 15 degrees west of north, and dips at an angle of about 80 degrees to the west. At Nolan's Trig. it is over a chain in width and consists of almost pure banded blue and white quartz, a little farther both north and south, however, it is of the usual hematite-bearing type; from the top of this hill, the belt can be seen extending in the form of low isolated hills for several miles both north and south. The third line lies about a mile to the westward of this, and is similar to it in all respects, but its extent appears to be more limited.

With the exception of the hills formed by these belts the greater part of the country is flat and covered with recent detrital deposits, especially to the west of the middle belt; eastward of this there is a greater extent of rock outcrops, these consisting of massive greenstones traversed by a few small hematite-bearing quartz lodes, and also by several north and south belts of schists within which the normal quartz reefs are usually found.

Eastward of Mount Varden, the country is more hilly, and consists of greenstone hills and ridges capped with ironstone conglomerate (laterite), these extending east for four or five miles till the main granite belt is reached.

The quartz reefs of this district are of two classes:—

- (a.) Lenticular quartz reefs associated with the hematite-bearing quartz lodes; and
- (b.) Quartz reefs of the normal type, occurring entirely in the greenstones. (*Photographs 9 and 10.*)

Class (a) is represented by the Spes Unica, City of Auckland, and King of Creation reefs, and class (b) by the Little Doris and Bungarra.

The principal mines working in this district at the time of my visit were the King of Creation, Spes Unica, Bungarra, and Little Doris.

### The Mines.

KING OF CREATION, G.M.L. 1382.—A wide belt of hematite-bearing quartz and altered greenstone schist (the continuation of the Mount Varden belt) runs through this lease, on a bearing slightly west of north; associated with it are veins and lenticular masses of quartz, the latter often of large size; these usually run



a few points more westerly than the schists, and overlap each other slightly, dipping with the schists at a steep angle to the west. These lenses are of white, glassy quartz, generally strongly laminated, and vary considerably in their gold contents, the best stone usually being found in the centre portion of the lens. In addition to these large makes of stone a number of small leaders are associated with the schists, usually running parallel to them; these, though small, are sometimes exceedingly rich.

Several shafts were put down on the property by previous owners, but little or no work was done from any of them, and they have since been abandoned; the deepest of them, which is about 5 feet below water level and still in soft country, is now being used as a water shaft, the water being fresh and drinkable. From this shaft, which is on the west side of the main belt of schists towards the north end, two crosscuts have been put in easterly under the outcrop of a couple of large quartz masses, one at 50 feet and one at water level (110 feet); of these the former is in about 100 feet, the whole length of it being in what is practically one large lode, consisting of highly altered greenstone schist highly impregnated with quartz in veins and gashes; running through and with this lode are five fair-sized quartz reefs, ranging from two to five feet in thickness, and about 10 to 20 feet apart. No work, however, has been done on any of these, though they are all said to carry gold; the bottom crosscut is in 40 feet, the first thirty of which are in practically solid quartz and the remaining ten in schist with seams of quartz; it is not in far enough to cut all the makes of stone met with above. A few tons of stone were crushed from a seam near the centre of this big make of stone, with very satisfactory results, but no further work has been done upon it. At present the only work being done on the property is in a large irregular opencut a little to the north of the water shaft; stone has been taken from this to a depth of about 30 feet, and is now being broken at about 15 to 20 feet from the surface; the reef in this cut averages about 6 feet in thickness, and is pretty low-grade, the best results being obtained as a rule near the centre of the reef. Two bulk crushings from this opencut are said to have averaged 14 dwts. and 18 dwts. respectively.

Towards the south end of the Lease, a small quartz leader running alongside a body of hematite-bearing quartz has been worked to a depth of 30 or 40 feet; this leader was only an inch or two in thickness, and was very short, but some exceptionally rich stone was taken out of it.

There is a large body of low-grade gold-bearing stone on this property, which seems well worthy of more systematic prospecting than has been given to it so far.

*King of Creation, G.M.L. 1382.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1904  | .. | .. | .. | 34.00        | 48.44           | 1.42          |
| 1905  | .. | .. | .. | 109.00       | 46.78           | .43           |
| Total | .. | .. | .. | 143.00       | 95.22           | .66           |

SPES UNICA, G.M.L. 1391.—Situated about half-a-mile south of the King of Creation, and on the same line of schist and hematite-bearing quartz lodes, which runs right through the centre of the lease. These so-called hematite-bearing quartz lodes, which are merely local alterations of the schists, vary from banded quartz and hematite through blue and white banded quartz to a merely slightly silicified ironstained schist. Associated with these, and running and dipping with them, are several fair-sized lenticular quartz reefs, these sometimes being up to four feet in thickness, but of no great length or regularity. The present workings are on one of these reefs on the western side of the main belt of schist, and consist merely of a vertical shaft sunk to a depth of 100 feet, at which point drives have been put in 90 feet north and 25 feet south along the reef, and a little stoping done from the north drive.

The reef is from two to three feet on the surface, but in this drive, is very irregular and consists of a series of broken lenses, varying a good deal in length and apparently pitching to the south; occasionally the quartz dies out altogether and its place is taken by schist, which usually carries a little gold; the best stone is where the quartz makes and fills the whole space between the walls of the lode.

Insufficient work has, however, been done on this reef to give a definite idea of its exact size or possibilities, but the work has proved that the quartz lenses are very irregular, and that they do not carry their size vertically.

In addition to this work, a second shaft has been sunk to a depth of 50 feet on a fair-sized lens of stone in the same line of reef some 80 feet farther north; this shaft was inaccessible, but the lens, which was some 3 feet wide on the surface, appeared to be cutting out rapidly.

The belt of schists is full of these lenses of quartz, varying from a couple of inches up to two or three feet in thickness and apparently all carrying gold, but being too short and irregular to be of much value. The schists themselves carry a little gold, but not sufficient to make them payable.

During 1905 this lease crushed 58.00 tons for a yield of 27.18ozs., giving an average of .46ozs. per ton.

**BUNGARRA, G.M.L. 1480.**—Situated about half-a-mile north-east of the King of Creation. — The reef occurs in a narrow belt of crushed greenstone, with massive greenstones on either side, which is still fairly soft in the lower workings, while the massive variety is very hard and solid. The work done consists of a main vertical shaft down 100 feet; at 30 feet a drive has been put in northerly along the reef for 110 feet, and this block stoped out to the surface, and in addition about 25 feet of driving has been done southerly at this same level; at the 100 feet level drives have been put in along the reef for 95 feet north and 20 feet south, and a little stoping done from the north drive just beside the shaft. The reef, which runs on a bearing of 345 degrees, and dips steeply to the westward, is very small and irregular, varying from a mere thread up to as much as 12 inches, and averaging about 6 inches; these larger makes of stone are mere bunches and do not carry their size for any distance, either vertically or horizontally. So far the best stone has been obtained from the bottom level, the last crushing from which is said to have given an average of nine to ten ounces.

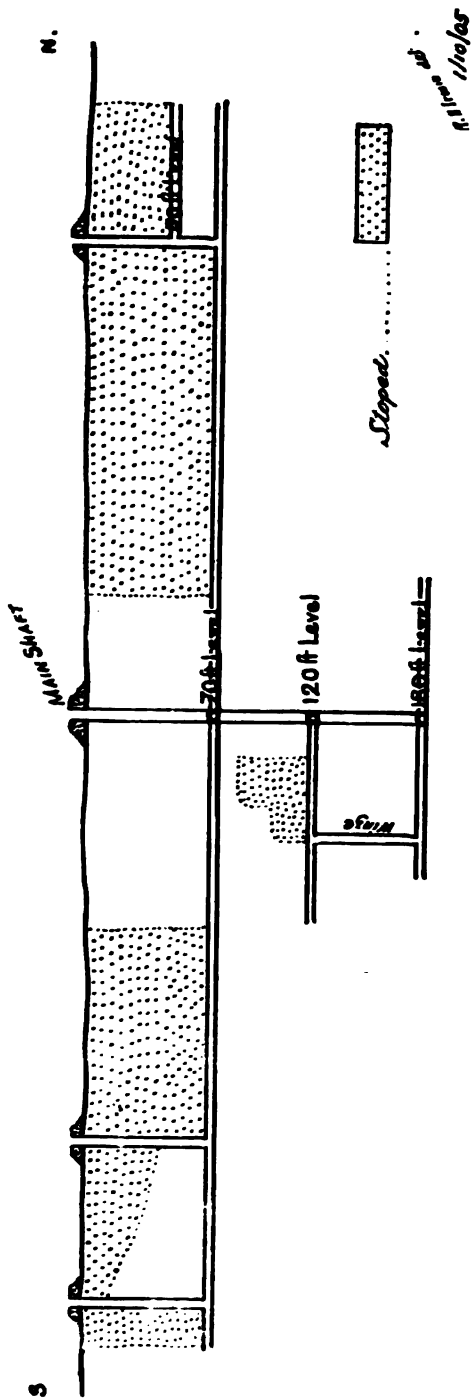
*Bungarra, G.M.L. 1480.*

| Year.      | Ore crushed. | Gold therefrom. | Rate per ton. |
|------------|--------------|-----------------|---------------|
|            | tons.        | fine ozs.       | ozs.          |
| 1905 .. .. | 39.00        | 292.72          | 7.51          |

**LITTLE DORIS, G.M.L. 771** (*Photograph 11*).—The class of deposit in this property is similar to that in the Bungarra, consisting of a small irregular quartz reef enclosed in a narrow belt of greenstone schists some 30 or 40 feet in width and bounded by hard compact massive greenstones. (Fig. 4). This belt of schist is full of small irregular quartz veins, most of which carry fair gold, all running with the foliation of the schists and dipping with them to the west. The main line of reef being worked is very irregular and bunchy; at the south end in the old workings it was about five feet in thickness, but in the present workings its maximum is about three feet, it varies from this down to a mere thread, often pinching out in a few feet; the bunches of stone are very irregular, and do not carry their size for any great distance either laterally or vertically, neither are they all uniform in their gold contents. The reef has been traced on the surface for some 800 feet on a bearing of about 345 degrees, and carries gold for the whole of this length, though, as before stated, the values vary a good deal; the stone carries a good deal of carbonate of copper, this rendering treatment somewhat difficult.

Water level is about 70 feet, the water being salt; it is being pumped from the bottom level at the rate of about 15,000 gallons per day.

FIG. 5.



SECTION SHEWING THE APPROXIMATE AMOUNT OF WORK DONE ON LITTLE DORIS G.M.L. 771. ERLISTOUN MT MARGARET G. F.  
SCALE 100 ft TO 1 INCH

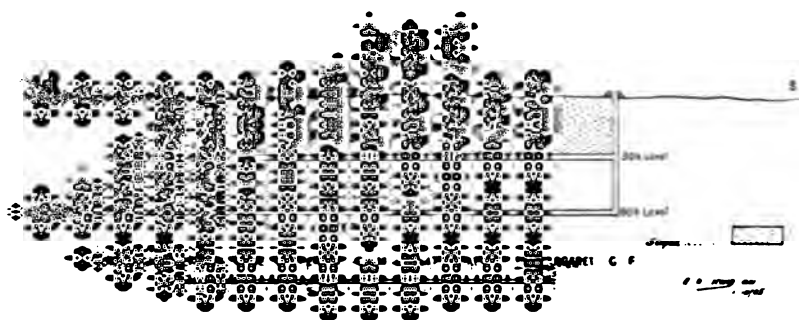




Govt. Photo. Litho.

Mountain.









The country in the vicinity of the reef (the schists) in the lower workings is still pretty soft, but the massive greenstones enclosing the schists are very hard and solid. The accompanying sketch section (Fig. 5) shows, from figures supplied by the manager, the approximate amount of work which has been done on this property up to the end of August, 1905.

*Little Doris, G.M.L. 771.*

| Year.       | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|--------------|-----------------|---------------|
|             | tons.        | fine ozs.       | ozs.          |
| 1898 .. ..  | 60.00        | 140.93          | 2.35          |
| 1899 .. ..  | 100.00       | 131.92          | 1.31          |
| 1900 .. ..  | 40.00        | 26.19           | .65           |
| 1901 .. ..  | 88.00        | 176.62          | 2.00          |
| 1902 .. ..  | 16.00        | 28.70           | 1.79          |
| 1903 .. ..  | 160.00       | 239.94          | 1.49          |
| 1904 .. ..  | 235.00       | 252.75          | 1.08          |
| 1905 .. ..  | 150.00       | 207.72          | 1.31          |
| Total .. .. | 849.00       | 1,204.67        | 1.41          |

**Kirkpatrick's or Little Battery.**

This centre is situated about seven miles north of the King of Creation, on the Duketon road; it is in the same belt of greenstones, but the banded quartz lodes are absent from this particular locality, though they re-appear again farther north at Baneygo and Eristoun. The country consists of greenstone schists foliated about north and south, and within these occur auriferous quartz reefs, running with the schists, and dipping with them to the east. These reefs are lenticular in habit, and mostly small, seldom exceeding a foot in thickness. Several of them have been worked with varying results, the most important being that known as Kirkpatrick's, on which a good deal of work has been done to a depth of 120 feet; this reef averages about a foot in thickness, but is very bunchy, often going from 18 inches to almost nothing in a few feet. A three-head battery is erected on the property and a good amount of gold has been won from it, the returns being as shown below. The water level is about 65 feet, the supply being salt and unuseable. In addition to these small north and south reefs several very large ones are found in this locality; these run in a general east and west direction, and are frequently 20 feet or more in thickness, outcropping for distances of 10 to 20 chains, and often forming razor-backed hills 40 to 50 feet in height; they are of white hungry-looking quartz and apparently carry no appreciable amount of gold.

### Erlistoun.

Erlistoun lies about seven miles north of Kirkpatrick's, on the continuation of the same belt of greenstones. A townsite was laid out here in the early days, but the only sign of it at the present time are the allotment pegs and one small hotel; the two localities where mining operations have been carried out are better known as the Mistake and the Baneygo, taking their names from the principal mines. The Mistake is situated about half-a-mile east, and Baneygo two miles north-west of the surveyed townsite of Erlistoun; this latter locality was, however, practically abandoned at the time of my visit; a large number of leases were taken up here and a lot of work done on them in the past. The country here is greenstone schist traversed by several very persistent belts of hematite-bearing quartz, one of which, about a mile to the west of the Baneygo, can be seen extending across country in a series of low hills north and south for several miles; another belt runs through the leases south of the Baneygo for over a mile, and, in addition, there are several other smaller belts all running pretty well north and south. Quartz reefs are associated with these belts, usually running alongside them, and though small, are said in some cases to have yielded very good results.

### The Mines.

**BANEYGO LEASE (G.M.L. 725).**—On this property a good deal of work has been done on a quartz reef running about north and south and dipping fairly steeply to the east. A main shaft has been sunk about 40 feet below water level (90 feet), and a little work done here; above water the reef has been stoped out from the 40 feet level to the surface over a length of 400 feet. These workings had been abandoned for some time past and were inaccessible. The reef is said to have been as much as six feet wide in places, but was very irregular and patchy; the shoot of gold is said to have cut out below the 40 feet level. On the adjoining block to the south the workings were also inaccessible; two parallel reefs have been worked here, and on the eastern one a block 800 feet in length has been taken out down to water level (85 feet). This reef dips west, does not come to the surface, except at the south end, but turns over and dips away easterly, the cap of the turn pitching to the north at a fairly flat angle; this eastern leg does not go down very far, and is not of such good grade as the western leg; the reef was small and very irregular, especially in the lower levels; the second reef lies a couple of chains farther east, and has had a good deal of work done on it; it is exactly similar to the eastern reef in all respects, except that it is somewhat smaller. This reef is partly along the junction of the greenstone schists with an intrusive mass of granite, and partly apparently, in the granite itself, though owing to the irregular nature of the old workings and the rotten nature of the country, it is very hard to get an exact idea of its mode of





occurrence; the body of granite is only of limited extent, as shown by the other workings. but it is, undoubtedly, to the presence of this and other similar bodies that the quartz reefs owe their contorted nature. There is a ten-head battery erected at the Baneygo, and at the time of my visit it was employed in crushing a small parcel from a prospecting show about six miles to the south-east.

*Baneygo Leases, G.M.Ls. 725 (720), 1313.*

| Year.        | Ore crushed. | Gold therefrom. | Rate per ton. |
|--------------|--------------|-----------------|---------------|
|              | tons.        | fine ozs.       | ozs.          |
| 1898 .. .. . | 85.00        | 149.48          | 1.75          |
| 1899 .. .. . | 100.00       | 258.93          | 2.59          |
| 1900 .. .. . | 612.00       | 839.97          | 1.37          |
| 1901 .. .. . | 157.00       | 180.11          | 1.14          |
| 1902 .. .. . | 1,329.00     | 1,769.78        | 1.33          |
| 1903 .. .. . | —            | —               | —             |
| 1904 .. .. . | 200.00       | 120.41          | .60           |
| 1905 .. .. . | 200.00       | 129.31          | .65           |
| Total .. ..  | 2,683.00     | 3,447.99        | 1.23          |

Between the Baneygo and Mistake Hill (half-a-mile south-east of Eristoun townsite), the country is greenstone schist, mostly flat and free from the occurrence of hematite-bearing quartz lodes; the greater part of it is covered with quartz rubble, resulting from the gradual breaking down of small quartz reefs in the schists; several very large quartz reefs occur here, one in particular about three-quarters of a mile west of Mistake Hill being some 30 feet in width and outcropping for 5 to 8 chains, and rising in one place fully 30 or 40 feet above the surrounding country; this, and most of the other large reefs, runs east and west; it is of white glassy quartz, and its gold contents appear to be *nil*.

Mistake Hill is a low rough ridge formed by a wide belt of banded and, occasionally, hematite-bearing quartz, running on a bearing slightly west of north, and traceable across country for some distance. The Mistake mine is situated on the flat about a quarter of a mile east of this hill; the surrounding country is a greenstone schist foliated in a general north and south direction.

MISTAKE, G.M.L. 1414 (*Photograph 12*). — With the exception of one or two small prospecting shows a few miles to the east, this was the only property on which any work was being done at the time of my visit. A large well-defined quartz reef runs through the lease and the adjoining ones on a bearing slightly east of north, and is easily traceable on the surface for a distance of nearly a mile. The reef is somewhat lenticular in form, being as much as six feet thick in some places and pinching to two in others; at the south end, in the present workings, it is much smaller and a good deal broken; most of the work has been done at this end, that

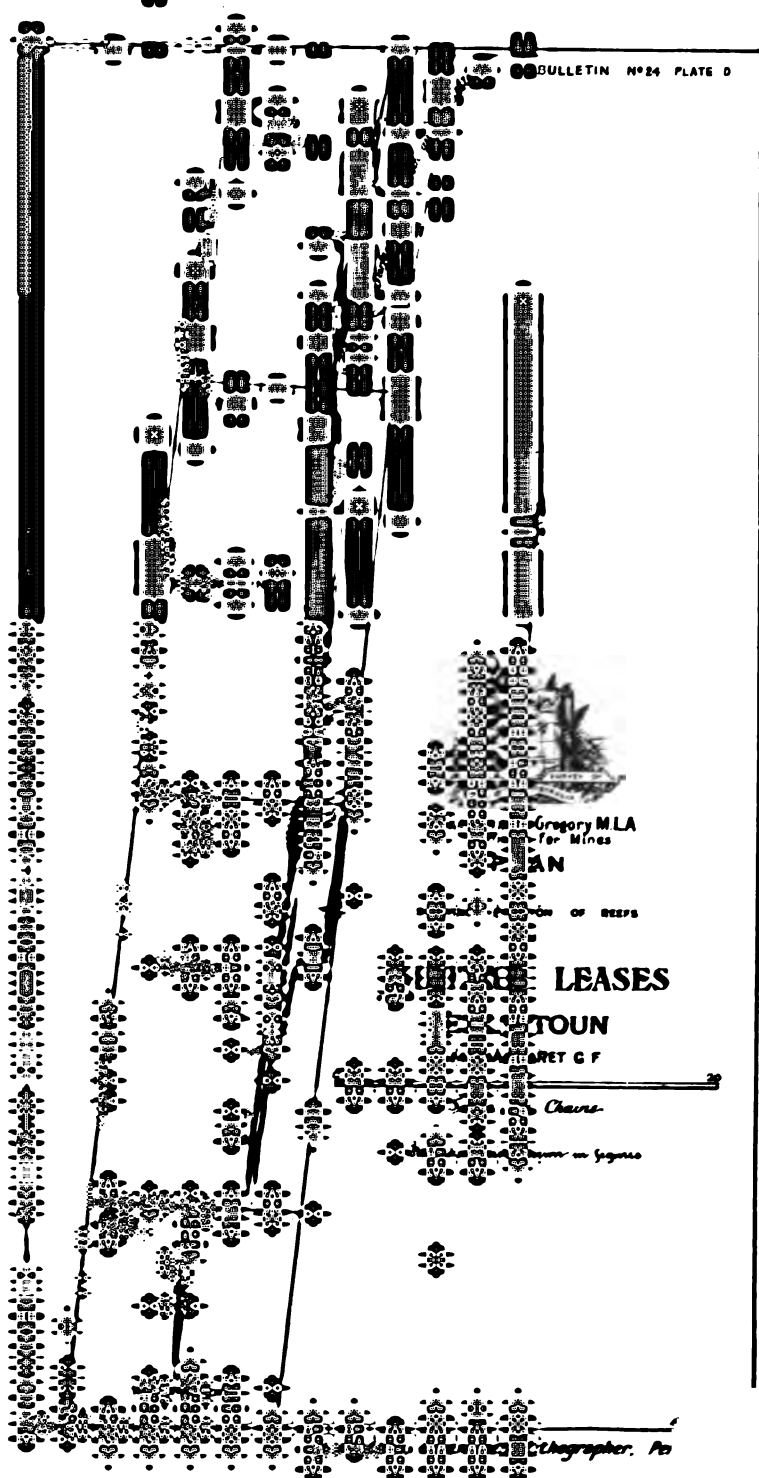
towards the north end consisting merely of a few opencuts, and several shafts sunk to about water level; the largest of these opencuts is some four to five chains in length, and 20 feet in depth, and shows the reef to be of white laminated quartz here about six feet wide, and dipping at an angle of about 45 degrees to the west; farther south the dip is much steeper. On the Mistake lease the reef is split up a good deal, there being three distinct lines here near the surface all uniting into one reef at water level. These reefs are small and irregular, varying from a couple of inches to nearly two feet in places; a considerable amount of work has been done on these reefs at about the middle of the lease, where a main vertical shaft has been sunk to a depth of 150 feet, although most of the work done has been from the 90 feet level to the surface; these workings were flooded, and therefore inaccessible at the time of my visit, and it was impossible to ascertain the extent of them. Work at the present time is being carried on near the south end of the block, where the reef has been opened up to water level (40 feet) for a length of, roughly, 250 feet, and the greater part of this block stope out to the surface; two lines of reef are exposed in these workings, meeting at water level, and of these the western is the better defined, and it is on this that most of the work has been done. These reefs are bunchy, and vary from a mere thread up to 18 inches, the average thickness being about 8 inches. The bunches are not regular and do not carry their size far, either longitudinally or vertically; along the water level the stone is more regular and continuous, but is still small, averaging from 6 to 8 inches. These south workings are apparently right on the end of the reef, as in a couple of prospecting shafts sunk two chains farther south no sign of it was found. The country is a greenstone schist, very soft and rotten down to water level, and said to be still soft and easy to work at the bottom of the main shaft (150 feet). Water level is about 40 feet, there being an abundant supply, but it is salt.

The accompanying plan (Plate D.) shows the positions and size of the main lines of reef.

The mine is equipped with a ten-head battery.

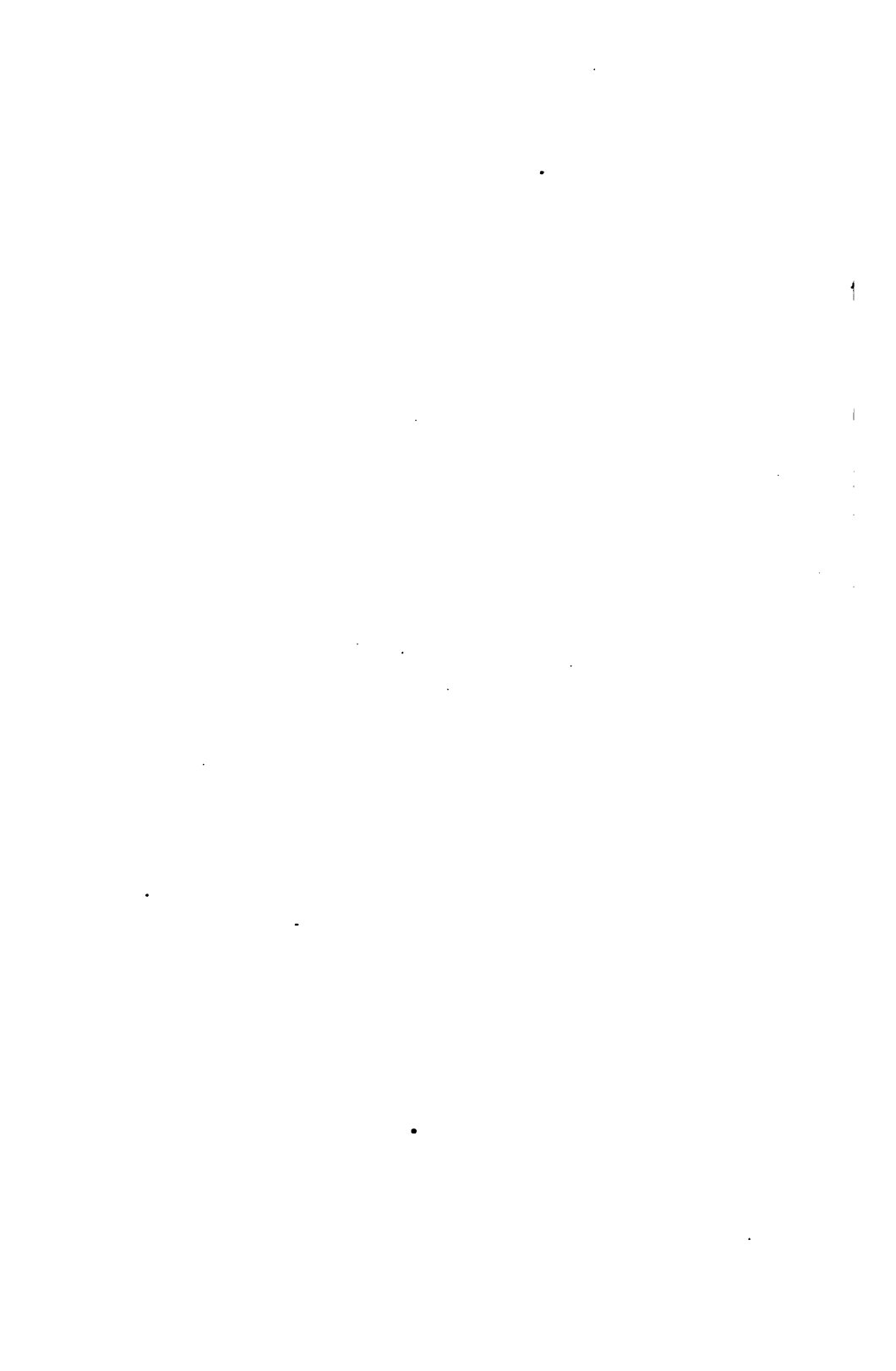
*Table showing the Yield of the Mistake Reef.*

| Year. | Name and Number of Lease.      | Ore crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|--------------------------------|--------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                |              |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                | tons.        | fine oss.       | oss.          | tons.        | fine oss.       | oss.                  |
| 1899  | Mistake, G.M.L. 1414 (796) ... | 220'00       | 151'19          | '69           |              |                 |                       |
| 1900  | Do. do. ...                    | 598'00       | 313'24          | '52           |              |                 |                       |
| 1901  | Do. do. ...                    | 96'00        | 52'44           | '53           |              |                 |                       |
| 1904  | Do. do. ...                    | 361'00       | 162'47          | '45           |              |                 |                       |
| 1905  | Do. do. ...                    | 278'00       | 404'26          | 1'48          |              |                 |                       |
|       |                                |              |                 |               | 1,546'00     | 1,063'60        | 70                    |
| 1899  | Mistake North, G.M.L. 795 ...  | 293'00       | 223'02          | '76           |              |                 |                       |
| 1900  | Do. do. ...                    | 300'00       | 156'54          | '52           |              |                 |                       |
|       |                                |              |                 |               | 593'00       | 379'56          | 64                    |
| 1900  | Mistake South, G.M.L. 968 ...  | 72'00        | 248'99          | 3'38          |              |                 |                       |
| 1901  | Do. do. ...                    | 33'00        | 202'13          | 6'12          |              |                 |                       |
|       |                                |              |                 |               | 105'00       | 446'12          | 4'25                  |
|       | Total ...                      | ...          | ...             | ...           | 2,244'00     | 1,909'28        | '85                   |



Chapman, P.





WESTRALIA TASMANIA (Dwyer and Party).—This is a lease recently pegged out some three and a-half miles from the Mistake, and on which, at the time of my visit, prospecting work was being vigorously carried out on a large white quartz reef running north and south through a belt of much altered greenstone schist. A vertical shaft is being put down on this reef and is down to a depth of about 100 feet, but so far no opening out has been done from it; the reef as exposed in this shaft is vertical, and about six feet in thickness, widening out near the bottom to nine feet; it can be traced on the surface for nearly five chains north of this shaft, but is cut off (on the surface) a short distance to the south; about five chains away in this direction is a large white quartz "blow" which is probably a continuation of the reef.

In sinking the shaft, from two to three feet of stone were taken from the west side of the reef, and this gave, at the Baneygo battery, an average return over the plates of 15 dwts.

About three chains west of this reef is a second fair-sized parallel quartz outcrop, but no work has been done on it, and again a few chains to the east is a well-defined but smallish reef running north and south alongside a hematite-bearing quartz lode, and dipping at an angle of 60 degrees to the east; this reef can be traced on the surface for about ten chains, and appears to average from one to two feet; it has been opened up in two places to a depth of from 20 to 30 feet, and in each of these is about 18 inches in width; no work beyond this has been done on it, neither has any stone been crushed. The country is greenstone schist foliated north and south, and traversed by numerous small but persistent hematite-bearing quartz lodes, these being more numerous on the adjoining block on the south; in the bottom of the shaft these schists are still very soft and easily worked, and, so far, there is no sign of water, this being because the property is situated on high ground.

Since visiting this locality I hear that the owners have abandoned this lease; this seems rather a pity, as the reef struck me as being one which was well worth further prospecting, especially as the bulk crushing from the shaft gave such satisfactory results.

On the block adjoining this on the south (Cox's) are a number of short lenticular quartz reefs running alongside the hematite-bearing lodes ("ironstone bars"), and a little work has been done on a couple of these. One lens two to three feet wide at the surface was worked for a length of about 30 feet and to a depth of about 20 feet, at which point it cut out on the side of the "bar," which was then followed down for another 50 feet, but without meeting with the reef again. A second lens a little farther south on the same bar was then opened up; there is here two to three feet of stone but so far very little work has been done on it. The "ironstone bars" on this lease are fairly numerous, but they are considerably faulted and contorted, and the quartz lenses are, as a rule, very irregular and of no length, and, though a few small parcels of stone may be taken out of them they are not likely to prove of any permanency.

## Duketon.

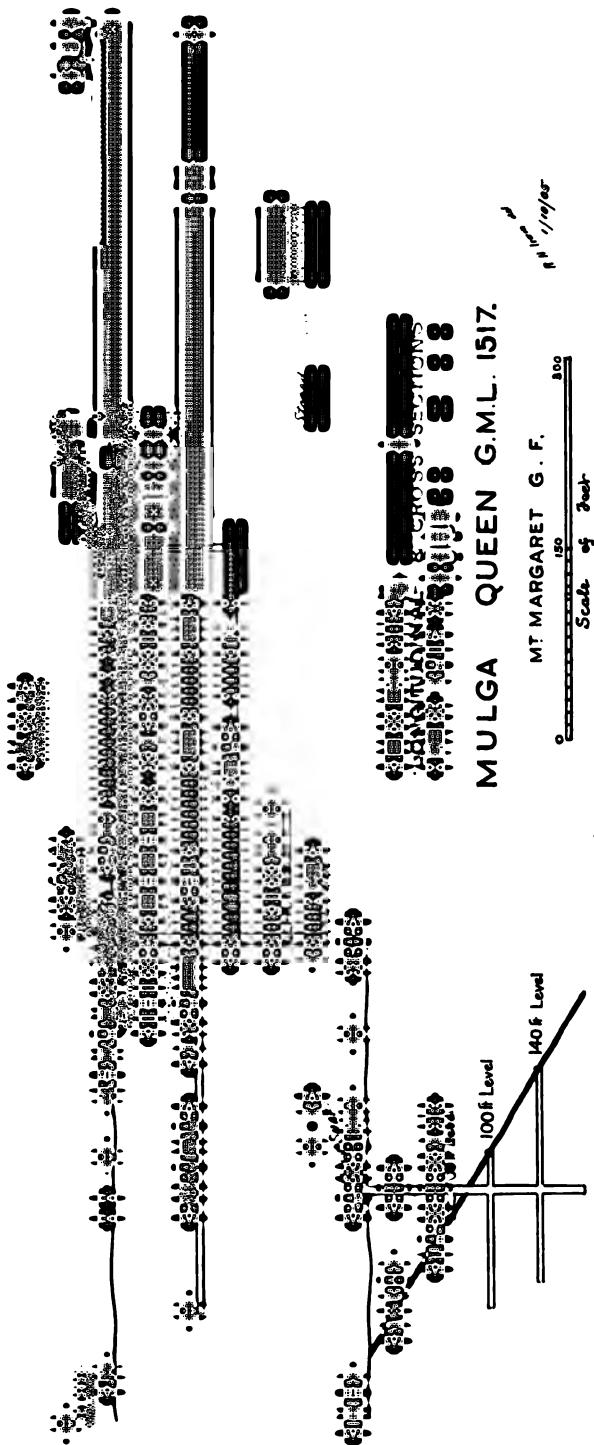
*(With a Map showing the position of the Auriferous Reefs, Plate V.)*

From Erlistoun to Duketon the road passes for the whole distance over country which is almost, without exception, dead level, and covered with a considerable thickness of recent deposits, and pretty thickly timbered with mulga, often of fair size. Owing to the thickness of these deposits, it is impossible to determine what the staple formation is, but it appears to be greenstone, though about six miles from Duketon there is a small outcrop of schists apparently similar to the granitic schists occurring at that place.

At Duketon the country is all dead level, and mostly devoid of rock outcrops except at Pinjie Eda Hill, about two miles south of the townsite, where there is a low ridge of hills trending southerly for a mile or so, and consisting of a fairly soft and weathered granitic schist, the lines of foliation of which strike about north-north-west and dip to the west.

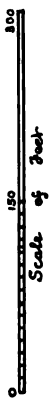
This is the only rock outcrop of any importance in the neighbourhood, and the country in the vicinity of the workings is so decomposed and rotten that it is very difficult to form a definite opinion as to what it really is, but it seems to me that the main line of reefs is situated along the junction of granitic and greenstone schists, being sometimes in the former and sometimes in the latter. The country west from here, and out towards Mulga Queen, consists of granitic schists, while to the eastwards are the greenstones extending for about six miles, when they give place to sand-plains which overlie the main eastern granite belt and extend inland for at least fifty or sixty miles. The junction of these two formations (the granitic and greenstone schists) runs on a bearing slightly west of north and east of south, and, though it is hidden beneath the covering of recent deposits, is approximately indicated by a series of very regular quartz reefs and by the workings on these reefs; these reefs have been followed for a distance of about five miles in a broken line, the greatest length of actual outcrop followed being from three quarters to one mile at the north end, and the greatest break in the line being about a mile; further systematic prospecting would probably reveal other reefs along this line, as they are almost entirely hidden beneath the surface covering and are undoubtedly more nearly continuous than shown by present developments. Most of the principal mines are situated along this line of reef, but there are other reefs in the schists, mostly small, and the greater part of the country is covered with quartz rubble, resulting from the gradual breaking down of quartz reefs and leaders.

At the time of my visit very little work was being done in this district, and most of the properties had been abandoned, principally owing to the fact that they were all low-grade and would not pay to work below water level, this, in some parts of the district being not



MULGA QUEEN G.M.L. 1517.  
8 CROSS SECTIONS  
1. HILLSIDE  
2. HILLSIDE  
3. HILLSIDE  
4. HILLSIDE  
5. HILLSIDE  
6. HILLSIDE  
7. HILLSIDE  
8. HILLSIDE

MT MARGARET G. F.



Scale of Feet



more than 12 feet below the surface ; the only properties in fact that were actually carrying on active mining operations at Duketon, were the Golden Spinifex (Lauriston), Rose of Persia, and the Wallaroo ; others on which a good deal of work has been done in the past but which are now abandoned, are the Monowai, Water Melon, and Morialta ; all these are on reefs following along the main junction of the granitic schists and the greenstones. One or two other properties have also been worked a few miles to the westward but these had all been abandoned for some time, and the workings were inaccessible.

### The Mines.

**MONOWAI, G.M.L. 810.**—This lease is situated at the extreme south end of the main line and is said to have been one of the first leases worked in the district, it was originally equipped with a ten-head battery, and a lot of work was done on it, but it is abandoned at the present time.

The reef has been proved through this lease and the adjoining ones to the north for a length of over half-a-mile, and what are possible continuations of it have been picked up for another half-mile ; it runs on a bearing slightly west of north and dips at a steep angle to the westward ; as exposed in a small opencut it is about two feet in thickness, and this appears to have been about its average size. The country in which the reef is found is a very decomposed and altered greenstone schist, but the granitic schists appear to come in a couple of chains farther west, while about half-a-mile north from here they are found forming the walls of what is probably the continuation of this same reef. The water level on this south block is 65 feet, but it gradually becomes shallower, proceeding northward.

**ROSE OF PERSIA, G.M.L. 1447.**—In this lease the reef appears to be following right along the junction of the granitic schists with the greenstones, but no crosscutting has been done, and the country in close proximity to the reef is so rotten and altered that it is very hard to say what some of it is ; the reef is rather bumpy, reaching a thickness of nearly six feet in one or two places, the average right through the workings being, however, about two feet ; these big makes of stone are, as a rule, poorer than the smaller portions of the reef. The length of reef, or rather reefs, as there are two at the north end a few feet apart, proved on the surface in this and the adjoining leases is about thirty chains and, as can be seen by reference to the accompanying plan (Plate V.), it runs a little west of north and is in direct line with the Monowai and Golden Spinifex reefs ; its dip is here about 75 to 80 degrees to the east. The accompanying sketch (Fig. 6) shows roughly the extent of the principal workings on the lease, and in addition to this there has been a little work done from a shaft about five chains farther north. The stone in the main workings

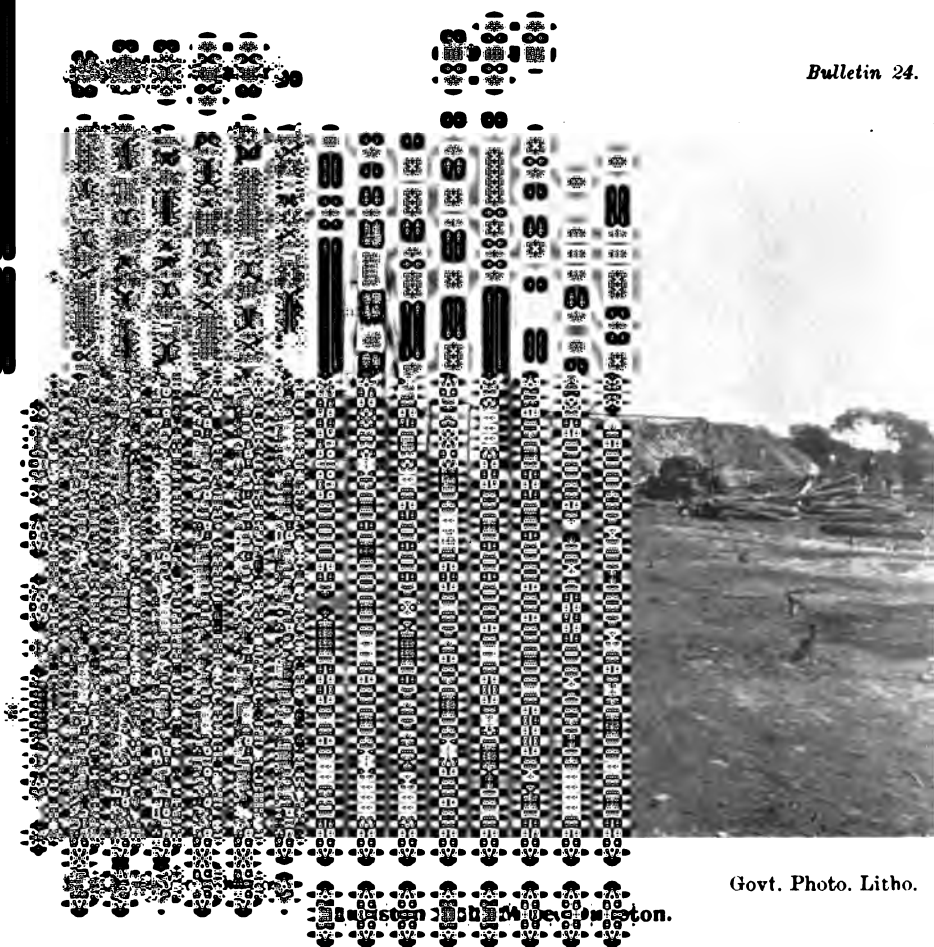
is not uniform in value and the shoots are not regular, but they all have a decided pitch to the south. Water level is about 63 feet, and the supply is fresh and drinkable, this being the case all through the district.

*Rose of Persia, G.M.L. 1447.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1903  | .. | .. | .. | 133.00       | 198.68          | 1.49          |
| 1904  | .. | .. | .. | 197.00       | 263.62          | 1.34          |
| 1905  | .. | .. | .. | 106.50       | 81.15           | .76           |
| Total | .. | .. | .. | 436.50       | 543.45          | 1.24          |

GOLDEN SPINIFEX AND LAURISTON, G.M.Ls. 1046, 1049. (*Photographs 13 and 14*).—These leases, which were originally worked as separate properties, are now amalgamated, and all work is being done on the Lauriston lease. A main vertical shaft has been sunk on this lease to a depth of 140 feet, and at the present time driving is being carried on along the reef at the 120 feet level; a good deal of work has been done above this, but the bottom level was the only one from which any work was being done at the time of my visit; the reef, as exposed along this drive, averages about 18 inches in width, being somewhat bunchy; in one place at the north end of the drive it is about five feet, but its values here are no good. Two other parallel makes of stone were cut in the crosscut from the shaft a few feet from the main line, these, however, were no good where cut, and no further work has been done upon them; the values of the main reef were not very good in the bottom level, the best being obtained at the south end, where it is expected that the Spinifex shoot will shortly be met with. Throughout the old workings the average size of the reef was about two feet, some bunches up to eight and nine feet being met with in the Spinifex lease; these, however, were as a rule, not much good, the best values being obtained in the smaller parts of the reef; the quartz is clean and white, and in places is strongly laminated. Down to the 30 feet level the reef dips to the east, but below this it takes a turn, and in the bottom workings is, if anything, dipping to the west; it nowhere comes to the surface on these leases, being covered by a deposit of surface "cement," varying in thickness from 10 to 15 feet; the general trend of it, like all the others on this line, is about north-north-west.

On the Spinifex lease a lot of work has been done, and a block about 500 feet in length has been taken out from the 60 feet level to the surface, in addition to which two vertical shafts were sunk to depths of 95 and 145 feet respectively, both of which were lost in the soft "running" ground met with below water; all these work-



Govt. Photo. Litho.

ston.







Govt. Photo. Litho.

keton.



ings were inaccessible. The reef in these leases is in granitic schists and runs parallel to their foliation, which is, however, not very strongly marked; these schists are very soft and rotten, especially at and a little below water level; and in some places below water owing to the large development of kaolin the country "runs" very considerably, and this, as above stated, has caused the loss of two main shafts on the Spinifex lease, and also necessitates the use of heavy timbering in the workings. The natural water level is about 30 feet, the supply being fresh and suitable for domestic purposes; at the present time it is being pumped from the 120 feet level on the Lauriston at the rate of 5,000 gallons per 24 hours.

*Table showing the yield of the Golden Spinifex Reef.*

| Year. | Name and Number of Lease.        | Ore crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|----------------------------------|--------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                  |              |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                  | tons.        | fine ozs.       | ozs.          | tons.        | fine ozs.       | ozs.                  |
| 1901  | Golden Spinifex, G.M.L. 1046 ... | 110'00       | 200'40          | 1'82          |              |                 |                       |
| 1903  | Do. do. ...                      | 776'00       | 494'70          | '83           |              |                 |                       |
| 1904  | Do. do. ...                      | 1,405'00     | 785'73          | '55           |              |                 |                       |
| 1905  | Do. do. ...                      | 324'00       | 246'04          | '72           |              |                 |                       |
|       |                                  |              |                 |               | 2,615'00     | 1,726'87        | '66                   |
| 1901  | Lauriston, G.M.L. 1049 ...       | 75'00        | 61'45           | 0'81          |              |                 |                       |
| 1903  | Do. do. ...                      | 225'00       | 434'07          | 1'92          |              |                 |                       |
| 1904  | Do. do. ...                      | 272'00       | 327'10          | 1'20          |              |                 |                       |
| 1905  | Do. do. ...                      | 22'00        | 22'91           | 1'04          |              |                 |                       |
|       |                                  |              |                 |               | 594'00       | 845'53          | 1'42                  |
|       | Total ...                        | ...          | ...             | ...           | 3,209'00     | 2,572'40        | '80                   |

WALLAROO, G.M.L. 1455.—This property is situated about a mile and a-half north-north-west of the Lauriston, and is apparently also on or close to the junction of the granitic schists with the greenstones, though in this case the reef itself is well within the greenstones; it has been opened up to a depth of 65 feet, and a block about 90 feet in length has been taken out between this level and the surface, or rather, between this and the bottom of the "cement" which covers the country round here to a depth of about 12 feet. Over this block the reef is said to have averaged about two feet; in the south face of the bottom drive it is nearly six feet and of pretty fair grade, while in the north face it is about two feet; the quartz is clean and white, and in places shows considerable lamination; it is crossed every few feet by a series of joints or "floors" which cut off the gold contents, the usual habit being, it is said, alternate makes of good and poor stone, these being defined by the above-mentioned floors. In the bottom level a good deal of sulphide is coming into the stone and in a short winze sunk from this level it is said to be pretty heavy.

The country is a very soft, rotten greenstone schist foliated parallel to the strike of the reef, which is between north-west and north; water is very abundant and comes in principally along the walls of the reef; its original level was from 13 to 14 feet.

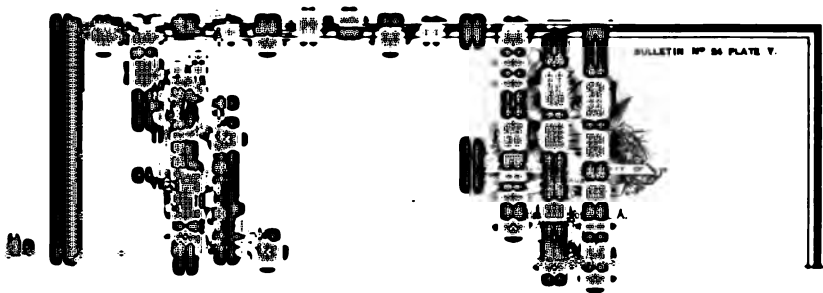
*Wallaroo, G.M.L. 1455.*

| Year.         | Ore crushed.   | Gold therefrom.     | Rate per ton. |
|---------------|----------------|---------------------|---------------|
| 1904 .. .. .  | tons.<br>77.00 | fine ozs.<br>155.93 | ozs.<br>2.02  |
| 1905 .. .. .  | 485.00         | 213.24              | .44           |
| Total .. .. . | 562.00         | 369.17              | .65           |

MORIALTA AND WATER MELON, G.M.Ls. 1236, 1451. — These leases are situated at the extreme north end of the line, and a good deal of work has been done upon them in the past, though they are both at present abandoned. The reef is traceable on these and the adjoining blocks for a distance of about half-a-mile; at its south end it is in greenstone schists and at its north in granitic schists; at this end there are two well-defined parallel reefs about two chains apart, both apparently in the granitic schists. The main line of reef appears to have had an average thickness of about three feet, though, like all those on this line, it is somewhat bunchy, being in some places as much as six feet, and in others again down to not more than one. None of the workings were accessible owing to their being flooded, the water level being only about twelve feet below the surface; this fact naturally greatly handicaps the prospector at this end of the field, more especially as there is frequently as much as ten or twelve feet of "cement" overlying the cap of the reef, which is thus placed right at or close to water level, and pumping has to be resorted to before any stone at all can be taken out. The water is fresh and suitable for domestic purposes.

*Table showing the Yield of the Morialta Reef.*

| Year. | Name and Number of Lease.       | Ore crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|---------------------------------|--------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                 |              |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                 | tons.        | fine ozs.       | ozs.          | tons.        | fine ozs.       | ozs.                  |
| 1903  | Morialta, G.M.L. 1236 ... ..    | 900.00       | 275.95          | .92           |              |                 |                       |
| 1904  | Do. do. ... ..                  | 163.00       | 328.00          | 1.40          |              |                 |                       |
| 1903  | Water Melon, G.M.L. 1451 ... .. | 105.00       | 71.66           | .68           | 463.00       | 506.95          | 1.08                  |
| 1904  | Do. do. ... ..                  | 74.00        | 63.91           | .86           |              |                 |                       |
|       | Total ... ..                    | ...          | ...             | ...           | 179.00       | 135.50          | .75                   |
|       |                                 |              |                 |               | 642.00       | 639.54          | .99                   |



BULLETIN N° 24 PLATE V.



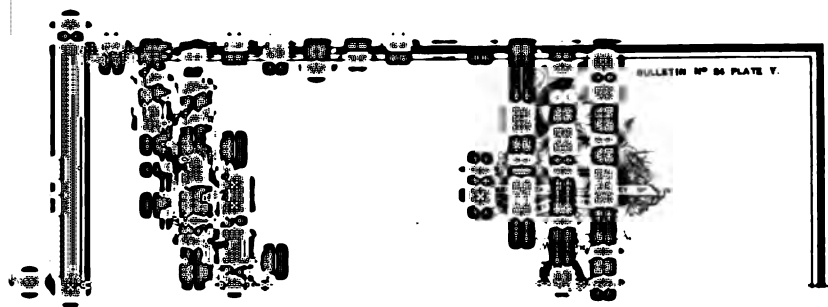
## Walleroo, G.M.L. 1455.

| Year.         | Ore crushed.   | Gold therefrom.     | Rate per ton. |
|---------------|----------------|---------------------|---------------|
| 1904 .. .. .  | tons.<br>77.00 | fine ozs.<br>155.93 | ozs.<br>2.02  |
| 1905 .. .. .  | 485.00         | 213.24              | .44           |
| Total .. .. . | 562.00         | 369.17              | .65           |

MORIALTA AND WATER MELON, G.M.Ls. 1236, 1451. — These leases are situated at the extreme north end of the line, and a good deal of work has been done upon them in the past, though they are both at present abandoned. The reef is traceable on these and the adjoining blocks for a distance of about half-a-mile; at its south end it is in greenstone schists and at its north in granitic schists; at this end there are two well-defined parallel reefs about two chains apart, both apparently in the granitic schists. The main line of reef appears to have had an average thickness of about three feet, though, like all those on this line, it is somewhat bumpy, being in some places as much as six feet, and in others again down to not more than one. None of the workings were accessible owing to their being flooded, the water level being only about twelve feet below the surface; this fact naturally greatly handicaps the prospector at this end of the field, more especially as there is frequently as much as ten or twelve feet of "cement" overlying the cap of the reef, which is thus placed right at or close to water level, and pumping has to be resorted to before any stone at all can be taken out. The water is fresh and suitable for domestic purposes.

Table showing the Yield of the Morialta Reef.

| Year. | Name and Number of Lease.      | Ore crushed. | Gold therefrom. | Rate per ton. | Total.       |                 | Average rate per ton. |
|-------|--------------------------------|--------------|-----------------|---------------|--------------|-----------------|-----------------------|
|       |                                |              |                 |               | Ore crushed. | Gold therefrom. |                       |
|       |                                | tons.        | fine ozs.       | ozs.          | tons.        | fine ozs.       | ozs.                  |
| 1903  | Morialta, G.M.L. 1236 .. ..    | 300.00       | 275.95          | .92           |              |                 |                       |
| 1904  | Do. do. .. ..                  | 163.00       | 238.00          | 1.40          |              |                 |                       |
| 1903  | Water Melon, G.M.L. 1451 .. .. | 105.00       | 71.68           | .68           | 463.00       | 508.95          | 1.08                  |
| 1904  | Do. do. .. ..                  | 74.00        | 63.91           | .86           |              |                 |                       |
|       |                                |              |                 |               | 179.00       | 135.59          | .75                   |
|       | Total .. ..                    | ...          | ...             | ...           | 642.00       | 639.54          | .99                   |







## Mulga Queen.

(With a plan showing the position of the Mulga Queen Reefs,  
Plan E.)

From Duketon to Mulga Queen the country is practically all dead level and covered with a varying thickness of recent deposits, the only rock outcrops of any extent being at Inji Jingi Hill and at Mount Maiden; both these outcrops are very much weathered and altered, but at both places the rock appears to be a granitic schist. Mount Maiden is a large flat-topped hill 80 to 100 feet in height and half-a-mile or so in length, trending about north-west, and formed of very much weathered granitic schists capped by a few feet of hard compact quartzite and quartz conglomerate, this latter being only of limited extent; both these (the quartzite and conglomerate) are undoubtedly formed *in situ*, the former being merely a local concentration of silica from the decomposition of the underlying schists, and the latter a cementing together of the quartz rubble with which the hill and the greater part of the country are thickly covered, the cementing material being the fine-grained quartzite. This quartz rubble undoubtedly owes its origin to the gradual breaking down and weathering of small quartz reefs in the schists, both may be described as residual deposits.

At Mulga Queen the country is a greenstone schist, the junction of this with the granitic schists being apparently between Mount Maiden and the townsite and in the near neighbourhood of the Famous Blue mine. Everywhere the rocks are very rotten and decomposed as far as opened up, and as the granitic schists are mostly fine-grained, it is very difficult to discriminate between the two classes owing to the amount of alteration and kaolinisation which has gone on in each of them.

Quartz reefs occur in both classes of rock, and are, as a rule, of fair size, but somewhat irregular and lenticular, this being a characteristic of nearly all the reefs in the Erlistoun district. Taking the district all through the reefs are essentially low-grade, and when the stone has to be carted six or ten miles to the battery there is not much profit left in it for the prospector.

The water level varies from 40 to 70 feet, the supply being invariably fresh and suitable for domestic purposes.

Good timber is fairly abundant, mulga of good size being obtainable anywhere, while white gum of good quality can be obtained from Erlistoun Creek, six to eight miles distant.

This centre is of comparatively recent discovery, and mining operations and business matters generally were pretty brisk at the time of my visit. The principal mine is the Mulga Queen, from which the town takes its name; this property is equipped with a ten-head mill, rock breakers, cyanide plant, and all accessories, and was the first mine in the district to erect machinery.

### The Mines.

The following is a brief description of such of the mines as were working at the time of my visit:—

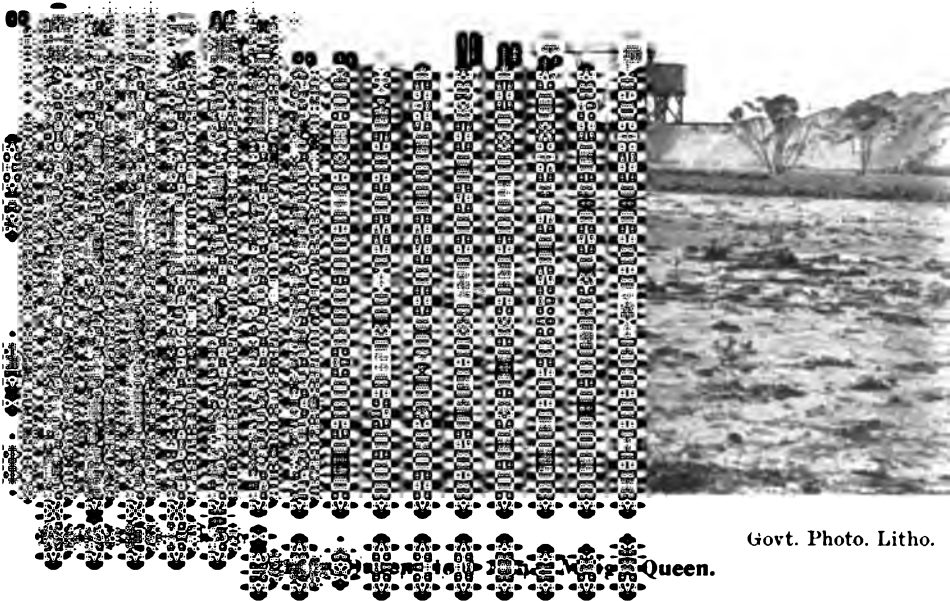
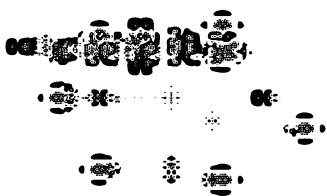
**MULGA QUEEN, G.M.L. 1517.** (*Photograph 15*).—Situated from half to three quarters of a mile west-north-west of the township. A good deal of work has been done here, as can be seen from the accompanying sketch section of the main workings. The reef, which has been proved through this and the adjoining north block (Plate E), for a distance of over half-a-mile, runs on a bearing of 325 degrees, and at the main shaft dips at an angle of about 30 degrees to the south-west (Fig. 7); both to the north and south of this its dip is considerably steeper; taking it right through, it is pretty regular in size, averaging about two feet; it is somewhat lenticular, but this is not so marked as in some of the reefs in this district, the biggest bunch being only about four feet, while it seldom goes below one foot; in one or two places towards the south end it is a little broken, where it appears to have gone through a harder belt of country, but this is only for a few feet. The stone carries a fair amount of sulphide at the north end close to the surface, but throughout the main workings there is little or none, though the stone is a good deal ironstained, and there are numerous vughs from which the sulphide has been leached out, these often showing fine gold on the walls. As a rule the gold is well in the stone and very fine, and the values of the reef so far have been fairly uniform right along its entire length. The country rock is a foliated coarse-grained greenstone with a little schist along the walls of the reef; it is very soft and rotten even in the bottom workings.

Water level is 69 feet, and the supply is fairly plentiful; it is fresh and makes good boiler and cyanide water.

#### *Mulga Queen, G.M.Ls. 1517, 1550.*

| Year.       |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------------|----|----|----|--------------|-----------------|---------------|
|             |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1904        | .. | .. | .. | 2,910.00     | 2,560.48        | .88           |
| 1905        | .. | .. | .. | 2,117.00     | 1,811.86        | .85           |
| Total .. .. |    |    |    | 5,027.00     | 4,372.34        | .86           |

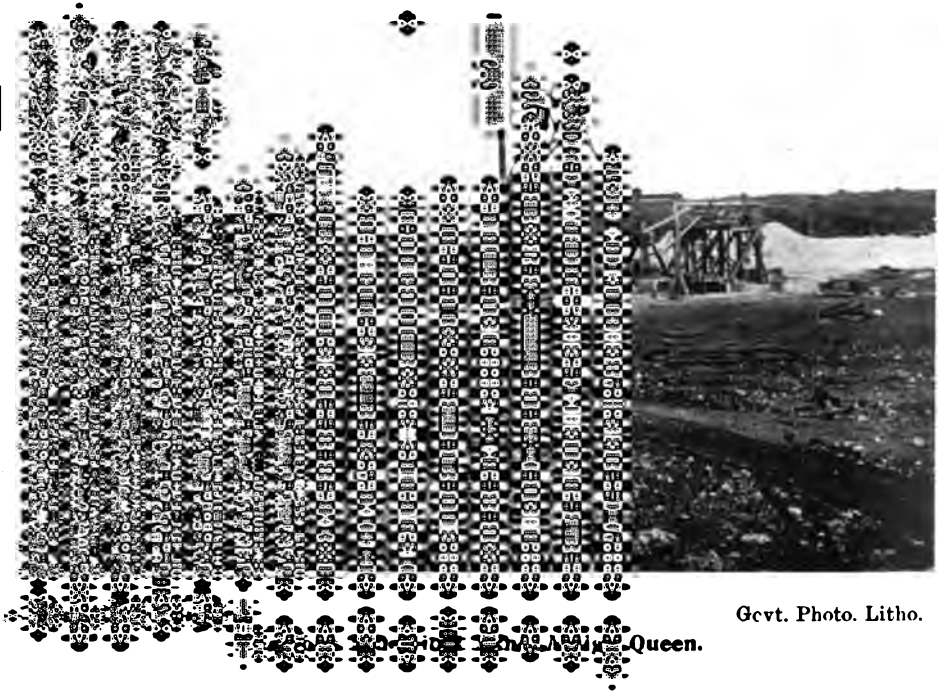
**MULGA QUEEN NO. 1 SOUTH, G.M.L. 1522.**—The main workings on this property are situated on what is possibly the southeasterly continuation of the Mulga Queen reef, though there appears to be a considerable break in it in the intervening lease. Here (Mulga Queen No. 1 South) the reef is somewhat more irregular and lenticular, and, on the average, is slightly smaller, being only about eighteen inches; as far as it was possible to see in the old



Govt. Photo. Litho.

Queen.





Govt. Photo. Litho.

Queen.



workings it seems to consist of a series of long lenses of various depths, the beginning of each lens lying on the hanging wall of the "tail" of the one above it, as shown in the accompanying diagram (Fig. 8); this lenticular habit appears to be only vertical and not longitudinal; the quartz is white and glassy, and, so far, free from sulphides. The general strike of the reef is 320 degrees, and its dip about 45 degrees to the south-west; it has been proved for a length of about fifteen chains, and may continue northerly for some distance farther; at the south end it appears to have cut out completely.

A good deal of work has been done on the lease, and several shafts have been put down to water level (40 feet) and the reef opened up for a length of about 450 feet at this level, and the greater part of this block stoped out to the surface. At the present time the owners are putting down a main vertical shaft, and have started to crosscut to cut the reef at 100 feet.

The country here is very soft and rotten, and consists of a fine-grained much kaolinised greenstone (?), which is difficult to work in below water owing to its running nature, and necessitates heavy timbering.

The greater part of the eastern portion of this lease is covered to a depth of twelve to fourteen feet with a fine-grained quartzite similar to that forming the capping of Mount Maiden; this probably is overlying an area of granitic rocks; the remainder of the lease, and, in fact, the whole of the country round about, is covered with the ordinary surface "cement" to a depth of ten to fifteen feet.

*Mulga Queen No. 1 South, G.M.L. 1522.*

| Year.        | Ore crushed. | Gold therefrom. | Rate per ton. |
|--------------|--------------|-----------------|---------------|
|              | tons.        | fine ozs.       | ozs.          |
| 1905 .. .. . | 472.50       | 351.31          | .74           |

FAMOUS BLUE, G.M.L. 1509 (*Photograph 16*).—Several lines of reef run through this property (Plate F.), but only one of them is being worked, this being a large well-defined quartz reef running about north-north-west, and dipping at a fairly flat angle to the eastward. As seen on the workings this reef has an average thickness of about four feet, but is somewhat irregular, varying from a minimum of 18 inches to a maximum of from 6 to 7 feet; it consists of a series of overlapping lenses coming in in the hanging wall, and having an average length of about 100 feet and pitching at a very flat angle to the south. The quartz is white and glassy, and the gold in it is very fine, occurring principally in vughs left by the oxidation and leaching out of pyrites. The average size of the reef



along the bottom level and the amount of work done on it can be seen from the accompanying diagrams (Fig. 9). This reef is in a foliated and highly decomposed greenstone, apparently close to its junction with what appears to be a belt of granitic schists extending easterly. Several other quartz outcrops occur in these schists a few chains east of the main line; some of these are of considerable size but no length; they run slightly more westerly than the main line, and one near the main shaft runs almost due east and west; these large outcrops appear to be merely surface makes, as a vertical shaft has been put down near the largest of them and a crosscut put in under it without cutting anything. Near the eastern boundary of the lease is a better defined reef running approximately parallel to the main shaft; it is, however, comparatively small, and no work of any description has been done upon it.

In the main reef some very rich stone was taken out from a large open cut; this shoot however has apparently cut out; the stone in the bottom level is somewhat patchy, some being very good and some the reverse; the shoots are small and not regular.

Water was struck at 78 feet (v.d.), and is fresh.

On the adjoining block on the north a little work has been done on the same reef, which here averages about four feet in thickness and has the same properties as in the main workings. It probably extends a good deal farther northwards, but is hidden beneath the recent deposits.

This property is equipped with a Huntingdon mill and rock breakers.

*Famous Blue, G.M.L. 1509.*

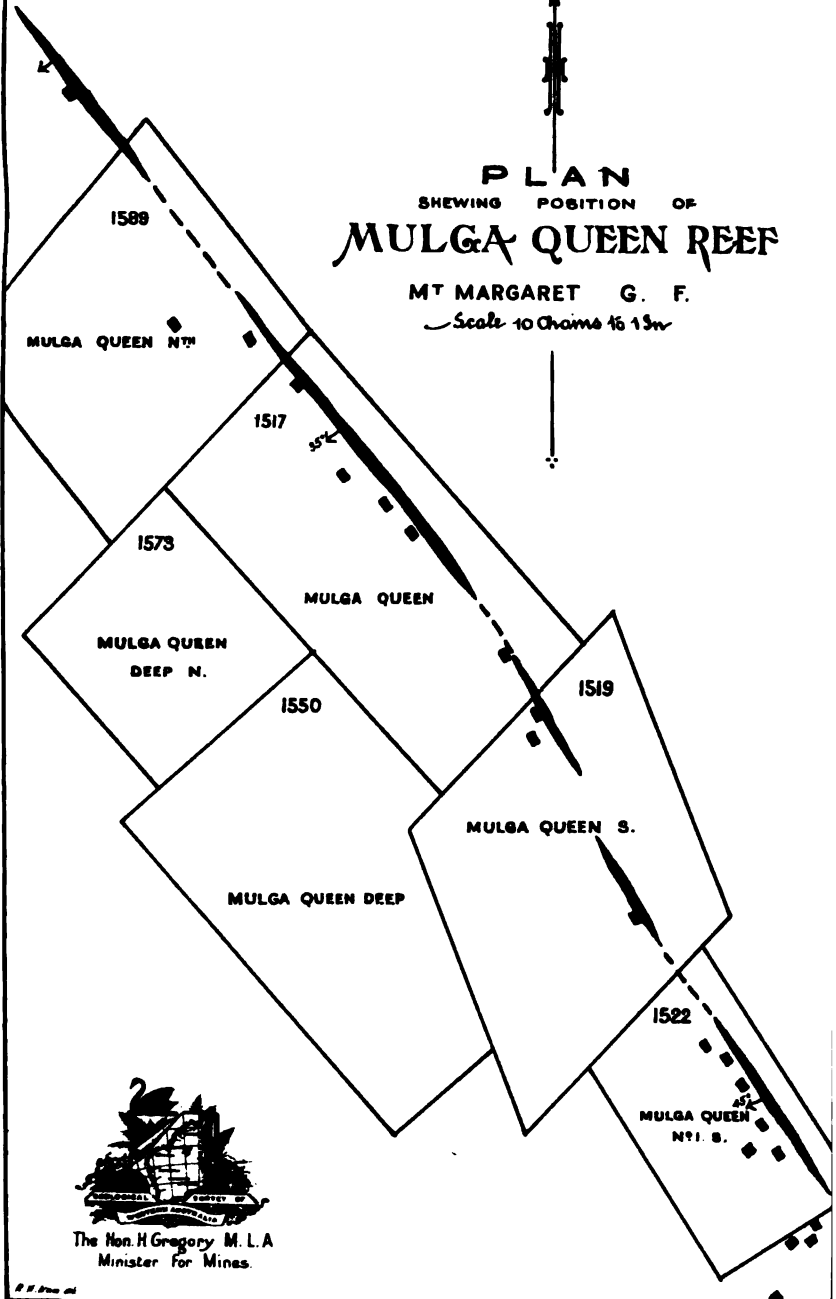
| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1904  | .. | .. | .. | 55.00        | 66.10           | 1.20          |
| 1905  | .. | .. | .. | 2,357.10     | 1,303.06        | .55           |
| Total | .. | .. |    | 2,412.10     | 1,369.16        | .57           |

FAMOUS, G.M.L. 1508.—A large irregular quartz reef runs through this property on a bearing slightly west of north, dipping at an angle of about 30 degrees to the west, and appears to be along or close to the junction of the greenstones with the granitic schists. Very little work has been done on it, and not much can be seen on the surface owing to the covering of recent deposits. The old workings are down to about forty feet, and the reef has been worked out in an irregular way down to this level for a length of about fifty feet; very little could be seen, but in the faces the average of the

PLAN  
SHEWING POSITION OF  
**MULGA QUEEN REEF**

MT MARGARET G. F.

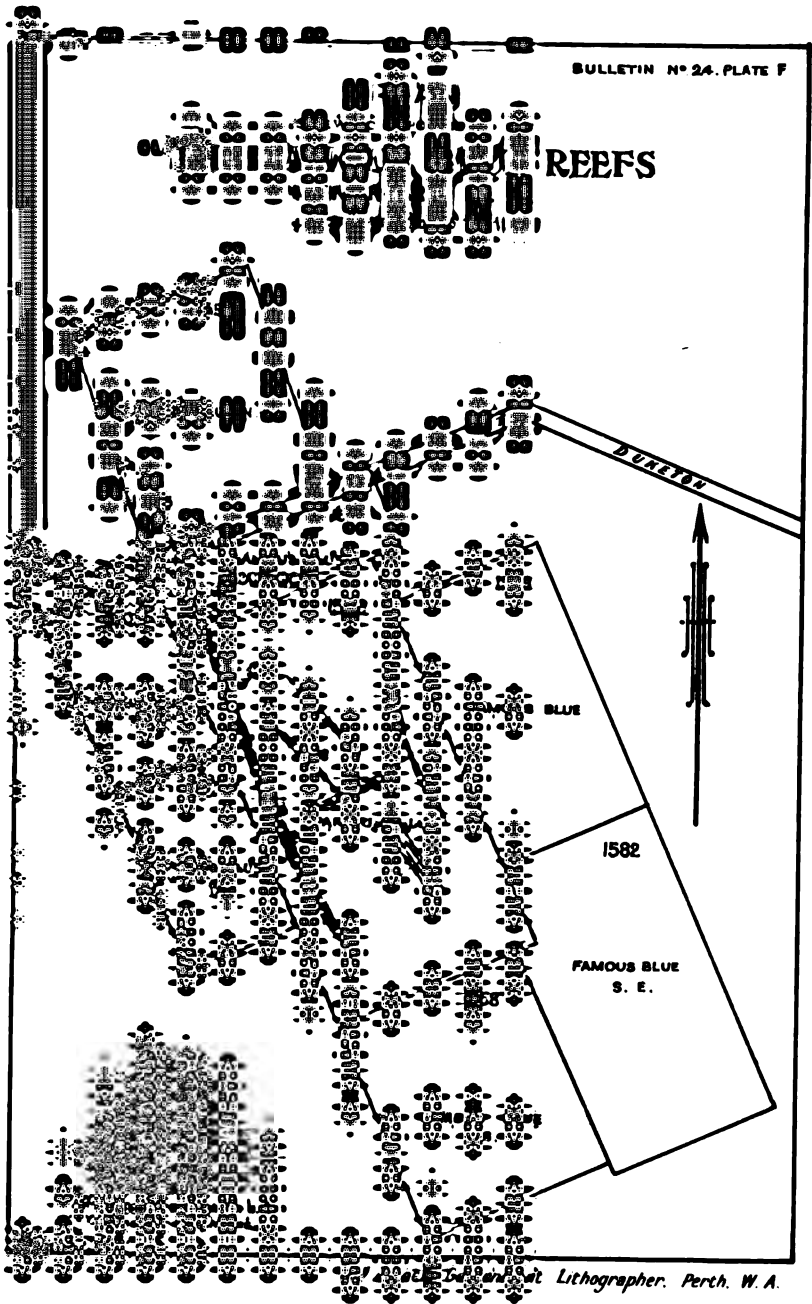
Scale 10 Chains to 1 in



The Hon. H. Gregory M. L. A.  
Minister for Mines.



# REEFS



Lithographer. Perth. W. A.

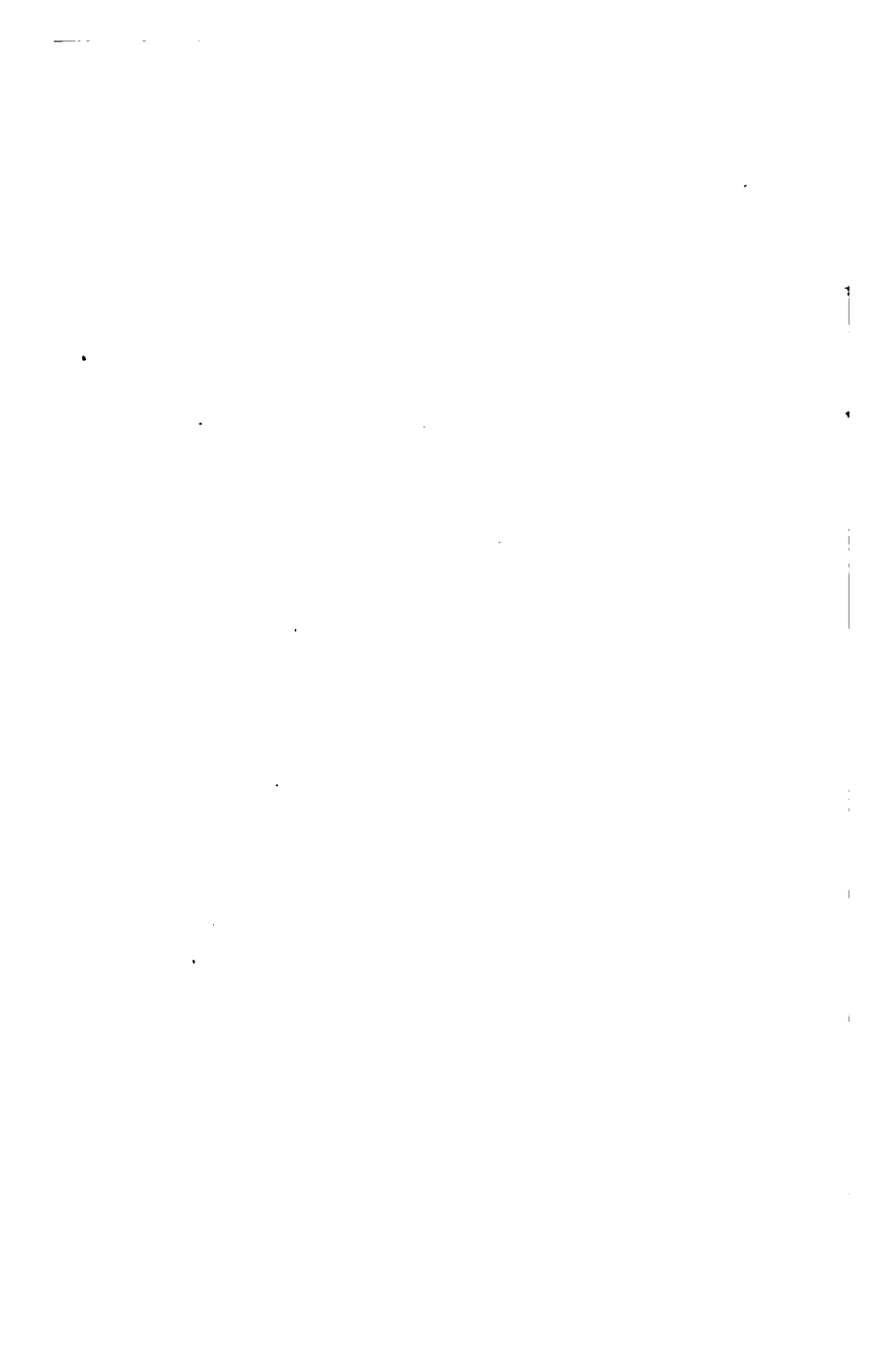


FIG. 8.

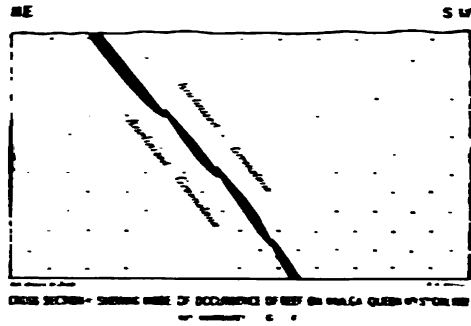
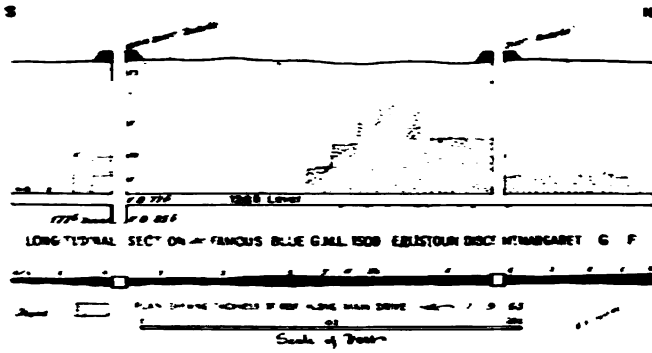


FIG. 9.





reef was about three feet, the stone being white and glassy, some of it showing coarse gold; some pockets of very rich stone were taken out of these workings, and the whole of it is said to be of pretty fair grade; only picked stone was crushed however.

The present owners are at present sinking a new main shaft and are crosscutting at the 100 feet level to meet the reef, and if developments are then satisfactory it is their intention to erect machinery.

*Famous, G.M.L. 1508.*

| Year. |    |    |    | Ore crushed. | Gold therefrom. | Rate per ton. |
|-------|----|----|----|--------------|-----------------|---------------|
|       |    |    |    | tons.        | fine ozs.       | ozs.          |
| 1904  | .. | .. | .. | 20.00        | 54.95           | 2.75          |
| 1905  | .. | .. | .. | 89.00        | 231.68          | 2.60          |
| Total |    |    |    | 109.00       | 286.63          | 2.63          |

About half-a-mile east of the Famous, a small party of men are engaged in dryblowing, this being the only alluvial patch worked in the district, with the exception of Frost and Baker's patch eight miles south-east; there is only a very small area of pay dirt, and very little gold is being got, the biggest piece so far being about 14 dwts. There is from 6 to 10 inches of dirt before reaching bottom; the gold appears to be shed from small quartz leaders which run through the country in all directions, and probably occurs principally at the points of intersection of these. The whole locality is covered with quartz rubble resulting from the gradual breaking down of similar and larger quartz reefs, and there seems no reason why other and larger alluvial patches should not be found in this locality.

There are several other shows in addition to those mentioned working in the district, principally in the neighbourhood of Eristoun Creek, some of which are said to be looking very well, and altogether at the time of my visit the place seemed very flourishing, which is more than could be said of the rest of the Eristoun district.



The following Table, compiled from the official statistics, shows the total gold Returns from the leases in the Erlistoun district, up to the end of 1905:—

| Name and Number of Lease.                                          | Ore crushed.     | Gold therefrom.     | Rate per ton. |
|--------------------------------------------------------------------|------------------|---------------------|---------------|
|                                                                    | tons.            | fine ozs.           | ozs.          |
| A1, G.M.L. 1521r .. .. .                                           | 46.00            | 54.48               | 1.18          |
| Baneygo Leases, G.M.Ls. 725r (720r), 1313r                         | 2,683.00         | 3,447.99            | 1.28          |
| Battler, G.M.L. 1591r .. .. .                                      | 35.00            | 35.92               | 1.02          |
| Battlers, G.M.L. 1409r .. .. .                                     | 212.00           | 454.06              | 2.14          |
| Ballantraye, G.M.L. 1599r .. .. .                                  | 44.00            | 30.36               | .69           |
| Bungarra, G.M.L. 1480r .. .. .                                     | 39.00            | 292.72              | 7.51          |
| Caledonia Leases, G.M.Ls. 1300r, 1322r ..                          | 1,000.00         | 1,559.07            | 1.56          |
| City of Auckland, G.M.L. 1450r .. .. .                             | 43.00            | 139.95              | 3.25          |
| Commonwealth, G.M.L. 1627r .. .. .                                 | 83.00            | 24.50               | .29           |
| Connemarra, G.M.L. 1552r .. .. .                                   | 96.50            | 29.91               | .31           |
| Crescent, G.M.L. 754r .. .. .                                      | 4.00             | *66.03              | —             |
| Easter Gift, G.M.L. 961r .. .. .                                   | 50.00            | 35.27               | .70           |
| Erlistoun Proprietary, G.M.L. 543r .. .. .                         | 80.00            | 84.50               | 1.56          |
| Erlistoun Proprietary G.M. Co., G.M.La. 795r (796r, 1185r) .. .. . | 1,138.00         | 641.36              | .56           |
| Erlistoun Queen, G.M.L. 1583r .. .. .                              | 4.50             | 11.55               | 2.56          |
| Ethel, G.M.L. 1568r .. .. .                                        | 23.00            | 31.87               | 1.38          |
| Eureka Reward, G.M.L. 1594r .. .. .                                | 31.00            | 9.70                | .31           |
| Famous, G.M.L. .. .. .                                             | 109.00           | 286.63              | 2.63          |
| Famous Blue, G.M.L. 1509 .. .. .                                   | 2,412.10         | 1,369.16            | .57           |
| Germania, G.M.L. 1660r .. .. .                                     | 102.50           | 83.90               | .81           |
| Gladys, G.M.L. 1539r (762r) .. .. .                                | 42.25            | 72.04               | 1.70          |
| Golden Boulder, G.M.L. 732r .. .. .                                | 23.00            | 55.94               | 2.93          |
| Golden Spinifex, G.M.L. 1046r .. .. .                              | 2,615.00         | 1,726.87            | .66           |
| Golden Star, G.M.L. 1533r .. .. .                                  | 20.00            | 8.57                | .42           |
| Idaho, G.M.L. 726r .. .. .                                         | 97.00            | 121.73              | 2.25          |
| King of Creation, G.M.L. 1382r .. .. .                             | 143.00           | 95.22               | .66           |
| King of Erlistoun, G.M.L. 797r .. .. .                             | 104.00           | 78.60               | .75           |
| Lauriston, G.M.L. 1049r .. .. .                                    | 594.00           | 845.53              | 1.42          |
| Lady Bella, G.M.L. 1460r .. .. .                                   | 55.00            | 41.38               | .75           |
| Lady Ethel, G.M.L. 1355r .. .. .                                   | 53.00            | 57.25               | 1.08          |
| Little Dorris, G.M.L. 771r .. .. .                                 | 849.00           | 1,204.67            | 1.41          |
| Marmont, G.M.L. 1491r .. .. .                                      | 60.50            | 17.62               | .29           |
| Mount Maiden Reward, G.M.L. 1432r ..                               | 376.50           | 171.65              | .45           |
| Mistake, G.M.L. 1414r .. .. .                                      | 1,546.00         | 1,083.60            | .70           |
| Mistake North, G.M.L. 795r .. .. .                                 | 593.00           | 379.56              | .64           |
| Mistake South, G.M.L. 968r .. .. .                                 | 105.00           | 446.12              | 4.25          |
| Morialta, G.M.L. 1236r .. .. .                                     | 463.00           | 503.95              | 1.08          |
| Mulga Queen, G.M.Ls. 1517r, 1550r .. ..                            | 5,027.00         | 4,372.34            | .86           |
| Mulga Queen No. 1 South, G.M.L. 1522r                              | 472.50           | 351.31              | .74           |
| O'Connor's Reward, G.M.L. 1510r .. ..                              | 39.50            | 45.28               | 1.14          |
| Parramatta, G.M.L. 1684r .. .. .                                   | 35.00            | 38.66               | 1.10          |
| Perseverance, G.M.L. 1593r .. .. .                                 | 116.50           | 71.19               | .61           |
| Rocaboni, G.M.L. 1643r .. .. .                                     | 24.00            | 43.33               | 1.80          |
| Rosa Kathleen, G.M.L. 1241r .. .. .                                | 87.00            | 80.29               | .92           |
| Rose of Persia, G.M.L. 1447r .. .. .                               | 436.50           | 543.45              | 1.24          |
| Rose of Persia No. 1 South, G.M.L. 1516r                           | 18.00            | 15.50               | .86           |
| Ruby, G.M.L. 1611r .. .. .                                         | 97.50            | 55.18               | .56           |
| Salt Bush Reward, R.C. 5r .. .. .                                  | ..               | † 22.95             | ..            |
| Spec Unica, G.M.L. 1391r .. .. .                                   | 58.00            | 27.18               | .46           |
| Sweet Nell, G.M.L. 1537r .. .. .                                   | 51.50            | † 161.08            | ..            |
| Sydney Mint, G.M.L. 144r .. .. .                                   | 31.00            | 59.84               | 1.93          |
| Two Jims, G.M.L. 978r .. .. .                                      | 8.00             | 22.82               | 2.85          |
| Wallaroo, G.M.L. 1455r .. .. .                                     | 562.00           | 369.17              | .65           |
| Watermelon, G.M.L. 1451 .. .. .                                    | 179.00           | 135.59              | .75           |
| Sundry Claims .. .. .                                              | 451.90           | 448.09              | .99           |
| Duketon State Battery .. .. .                                      | ..               | § 24.60             | ..            |
| District generally .. .. .                                         | ..               | † 1,099.43          | ..            |
| <b>Total .. .. .</b>                                               | <b>23,669.75</b> | <b>   22,495.08</b> | <b>.95</b>    |

\* Includes 45.00ozs. dolled and specimens.  
dolled and specimens.

† Alluvial.

‡ Includes 56.02ozs

§ By cyanide.

|| Exclusive of alluvial.

## Cosmo Newberry Ranges.

(*Frontispiece.*)

The track to the Cosmo Newberry Ranges leaves the main Laverton to Duketon road at a point about half-a-mile north of Kirkpatrick's Well and runs almost due east from this point for about 45 miles until the Ranges are reached. For the first two or three miles, the country consists of greenstone ridges covered with ironstone conglomerate, then red loamy plains covered with a heavy growth of mulga, these continuing for another three miles, when the main body of granite makes its appearance and runs continuously out to the ranges, the greater part of it being covered by sand plains and spinifex, the granite outcropping through these occasionally as low rough ridges and "breakaways."

As shown on the latest issue of the Lands Department's State Map, these ranges are situated about 60 miles to the north-east of Laverton townsite. They consist of a series of low hills and ridges trending in a general north-north-west and south-south-east direction, and having a maximum length of about ten miles, and a breadth of from three to five miles. At their south end they split into two distinct arms, the more westerly of which runs nearly north and south, and extends several miles farther south than the other. Surrounding this belt of hills on all sides are extensive sand plains covered with spinifex, these being the remains of an old granite tableland. The rocks forming the hills themselves consist of massive and foliated greenstones of the type usually found on the Eastern goldfields; intruded into them are dykes and masses of acidic rocks, which vary from a typical coarse-grained granite to fine compact quartzites and felsites. At Split Rock, which is situated near the western limit of the ranges, there is a considerable extent of granitic rocks outcropping over an area of about a square mile and apparently entirely surrounded by the greenstones, which, however, are for the most part hidden to the westward by a shallow depth of recent detrital deposits. This body of granite dies out about thirty chains north of Split Rock, but a series of acidic dykes run on in a general northerly direction for two or three miles, gradually becoming fewer as they go north. These dykes are found running in all directions, though their more usual trend is roughly north and south; they vary in thickness from a few feet to over a chain. The greenstones are as a rule considerably foliated close to their junction with them, the foliation being parallel to the trend of the dykes; quartz veins and masses are often associated with them, occurring along their junction with the schists, they are, however, seldom of any great size or regularity.

From Split Rock to the Government Well—a line across about the centre of the ranges—a traverse shows the granite extending for

about a mile, then half-a-mile of greenstone schists intersected by numerous granitic dykes, and then massive and foliated greenstones extending to the well, where the schists make their appearance again and continue for half-a-mile or so to the junction with the main eastern body of granite. This eastern junction runs very regularly on a bearing almost due north-north-west and south-south-east, the granite, however, only outcropping here and there over small areas, being for the most part hidden beneath sand plains resulting from its gradual weathering.

About four miles west of the well is what is known as the "Find," this being the first (?) lease worked in this district. The country here consists of foliated greenstones intersected by a few granitic dykes, these being the northern end of the series extending up from Split Rock. Northwards from this line—from the well to the Find—the hills extend for three or four miles, the rocks being mostly massive whilst the acidic dykes are few and far between. The greater part of the hills and ridges over this area are capped with ironstone conglomerate, this being especially the case on the eastern side of the ranges. South from the same line, there are no deposits of this conglomerate, the rocks outcropping on the surface and being very hard and practically unweathered.

In addition to the acidic dykes, a few basic (diabase) dykes intersect the greenstones, one of these towards the southern end of the hills being upwards of a chain in width, and traceable in a north west and south-east direction for over a mile. The greenstones on the whole at the south end of the ranges are more massive than those at the north, and are also intersected by a number of acidic dykes, these usually being a very fine-grained felsite, and on the surface often having very much the appearance of quartz reefs.

Throughout the greenstone area occur numerous quartz reefs; these are for the most part small and very irregular, they are found principally in the schists, in which they occur as lenticular gashea, or series of gashea, running with the foliation and having no defined course and seldom any great length, though occasionally the lenses are of considerable width. The quartz, as a rule, is white and glassy and generally very low in gold contents, although some of the smaller leaders occasionally carry good values. Quartz reefs and masses also often occur in association with the acidic dykes, being usually found along the junction of these latter with the greenstones; they are often of considerable thickness, but are very irregular and seldom extend for more than two or three chains in length, and their gold contents, as far as it was possible to test them, are generally from nil to a little better than traces. The district appears to have been pretty well prospected, and almost every quartz reef in the place bears marks of the pick.

Several leases have been pegged out and applied for at different times, but so far no applications have been approved, and with one or two exceptions little or no work has been done on them, neither has any stone been crushed, nor were any of them being worked at the time of my visit. The following, however, is a brief description of the class of deposit on those leases on which any work at all had been done.

■ About twenty chains west of Split Rock, several potholes have been put down on a line of reef running on a bearing of about 350 degrees, and apparently dipping steeply to the eastward; these potholes, the deepest of which is only four or five feet, show the reef to consist of white glassy quartz which is strongly laminated; it is about four feet in thickness at the south end and about two at the north, and can be followed in a very regular line for about fifteen chains; it is in a narrow belt of greenstone schist which is enclosed between two acidic dykes and runs parallel to the foliation of the schists. It is about the best defined and most regular reef (on the surface) seen in the district, but is too low grade to pay under existing conditions. A number of samples were taken by myself, and these gave by dish assay results varying from traces to two or three dwts.

Some sixty chains north-north-west from Split Rock a little work has been done on a lease which I was informed had been pegged and applied for under the name of the Kensington. The country here consists of greenstone schists intersected by numerous granitic dykes and masses and is very hard right on the surface; several fair sized irregular lenses of quartz occur alongside these dykes but appear to be of no value; several small quartz leaders also occur in the greenstone schists, and on one of these, occurring in a narrow belt of the schists, a little work has been done. This work consists of two or three potholes sunk to a depth of a few feet, which show the leader to be of an average thickness of about two inches, varying from a mere thread up to five or six inches at its biggest, and running with the foliation of the schists and dipping with them at a steep angle to the eastward; it can be followed on the surface in a not too regular course for only about two chains and, as the best results obtained from it by dish assay were about thirty dwts., some of the samples giving but little better than traces, I do not think it is likely to prove of much value under present conditions, more especially as, from its mode of occurrence, it is likely to cut out at any minute.

Four miles west of the well and about three and a-half miles north-north-west from Split Rock are the leases recently held under option by the Curzon's Syndicate, but at present lying idle. These comprise two twenty-four acre blocks, the Cosmo and the Lord Kitchener, on both of which a little work has been done. The country is mostly greenstone schists intersected by numerous granitic

dykes, these being more numerous in the southern block. On the north block, a vertical shaft has been sunk to a depth of thirty feet on a couple of quartz leaders, two or three feet apart; these, as seen in the shaft, are from 8 to 12 inches in thickness, and run about vertically; the quartz is white and glassy, and a series of samples taken by myself gave by dish assay results varying from traces up to ten or twelve dwts.; these not being good enough to render the proposition a payable one under existing conditions. These leaders run about north-west and south-east, and are only traceable for a short distance on the surface; they appear to me to be merely the fillings of small gashes in the greenstone schists and not likely to be permanent in depth. About half-a-chain east of the shaft is the outcrop of a large white quartz reef running about north and south; this reef is traceable on the surface for a distance of about twenty chains, but is somewhat irregular, and to the south is broken here and there by intrusive granite dykes; its gold contents, as far as tested, appear to be *nil*.

On the adjoining block on the south several potholes have been put down on a quartz leader which appears to be following the junction of a granite dyke with the greenstone schists, and is traceable on the surface for a distance of about two chains. At the north end, a hole has been sunk on it to a depth of about twelve feet exposing a reef twelve inches wide of white glassy hungry-looking quartz, while about a chain to the south of this, a second hole shows it to have pinched to a mere thread. Several samples were taken from it and the best of them only gave results equal to a few dwts., whilst others never gave a trace of gold. The country here is very hard right to the surface, and in view of this fact these small leaders would have to be exceptionally rich to pay to work, especially with the nearest battery forty-five miles away.

There are also one or two other reefs in the locality on which a pothole or two have been put down, but the above are the most important.

Taking the district all through, the reefs are, generally speaking, small and irregular, and so far the best of them have not proved of sufficient size or value to pay for working, and moreover, I am of opinion that very few of them would prove so even under the most favourable conditions.

As regards the watersupply of the district, there is a Government well on the eastern side of the range, the supply from which is, however, very limited, and during the dry season is not more than twenty gallons a day; the well, in order to be of any permanent use, requires to be sunk another twenty feet. Three miles south-south-east from this well is a good soak in a small creek running eastward through the hills; judging by its appearance at the time of my visit, after a protracted dry season, this soak should be, if not drawn too heavily

upon, practically permanent ; we were compelled to resort to it to water our camels during our stay at the Range as there was not a sufficient supply in the well for our own use and theirs. In addition to these supplies, there is a large rock-hole at Split Rock which is capable of holding several hundreds of gallons, and which lasts for some weeks after rains.

There is also a second Government well on the road out, about twenty miles from Kirkpatrick's ; this well, a shallow one, had a good supply of water in it at the time of my visit—there had been good rains a few months before—but is said to occasionally give out after a prolonged dry season.

## The Country at Mount Shenton and Mount Venn.

Mount Shenton, situated about eighty miles slightly to the east of north-east of Laverton, and thirty miles east of the Cosmo Newberry Ranges, forms the highest point of a range of hills running nearly north and south for several miles and rising abruptly out of the sand plains which surround them on all sides. The main axis of this range is formed by a large belt of hematite-bearing quartz often a chain or more in width and dipping at an angle of about 60 degrees to the east ; this is often considerably contorted and foliated and varies a good deal in its composition, parts of it being almost free from iron, whilst others again appear to be exceptionally rich. The surrounding rock is greenstone schist, and appears to be a crushed and altered quartz diorite.

The full extent of the range is some three miles in length by about half-a-mile in width, the highest point being roughly 250 feet above the surrounding sand plains. The southerly extension of the belt is Mount Grant, a large hill some 250 feet in height about three miles south to south-east of Mount Shenton, formed by a similar belt of hematite-bearing quartz a chain or more in width and dipping at an angle of about 60 degrees to the east ; intermediate between the two hills, the belt outcrops in one or two places in the form of low hills and is apparently continuous right along, though the greater part of it is hidden beneath the sand plains.

There appear to be no quartz reefs in the Mount Shenton greenstones, neither are there any associated with the main hematite-bearing quartz lode, and this, as far as tested, appears to be practically free from gold.

Eastward from Mount Shenton, the sand plains continue for a distance of about three miles when there is a fairly extensive outcrop of granite, the plains then extending on eastward indefinitely; this outcrop is in the form of low bare hills and ridges, the general trend of which is about south-south-east and which extend almost continuously to the neighbourhood of Mount Venn, where there is a much more extensive development of them than at the north end. This granite is a coarse-grained pink coloured variety and appears to be newer than and intrusive into the main body of granite which occupies the greater portion of the eastern half of this State, and the denudation of which has resulted in the formation of the great sandy tablelands of the interior; there is, however, no direct evidence on this point either one way or the other, but there is, near Mount Grant, a considerable area of granite porphyry which appears to be closely allied to this body of granite, and which is undoubtedly newer than both the main body of granite and the greenstones.

These granite hills form the eastern boundary of the greenstone ranges of which Mount Grant and Mount Venn are the highest points, the general trend of this junction being about south to south-east; the hills, however, die out just before Mount Venn is reached and give place to sand plains extending easterly and south-easterly indefinitely.

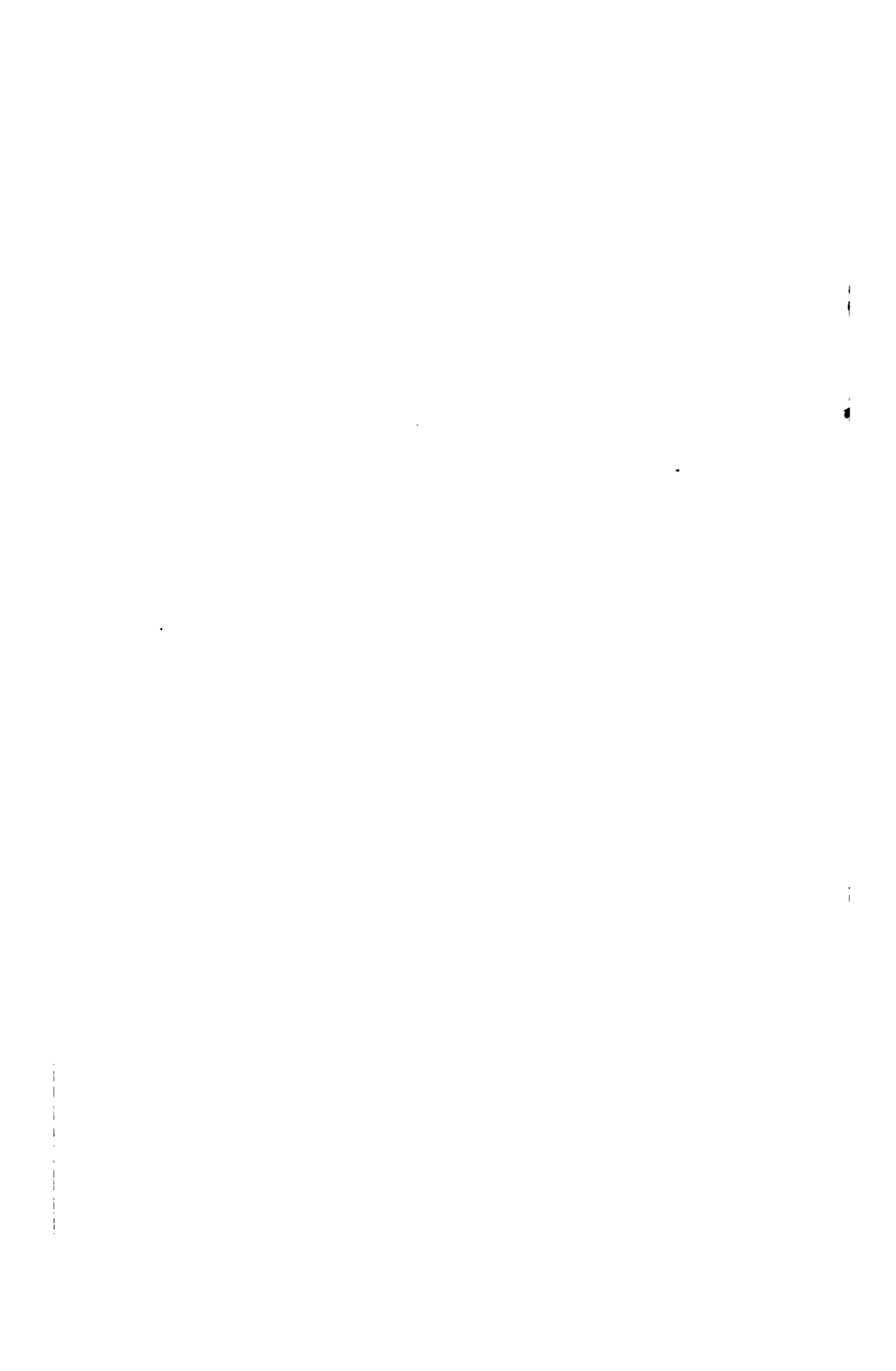
The length of the range of hills which includes Mount Grant and Mount Venn is roughly some seven miles, but its lateral extent is very irregular, varying from a maximum of about five miles down to half-a-mile, and having an average of less than two miles. The rocks comprising them are greenstones intersected by masses and dykes of acidic rocks, these latter being largely developed a little to the south-east of Mount Grant, where there is an area of them over a mile in extent consisting of a fairly coarse-grained quartz porphyry apparently closely related to the large body of granite a little farther east; southward of this, towards Mount Venn, are numbers of felsite and granitic dykes often of large size running in all directions through the greenstones. These greenstones are both massive and foliated, the latter variety being most largely developed at the northern end, where it is a crushed diorite similar to that of Mount Shenton. In the vicinity of Mount Venn, the rocks are entirely massive and consist of a coarse-grained augite rock very different to the usual type of greenstone; a section of this rock [6569] shows it to consist of augite and plagioclase feldspar in about equal proportions, the former being the typical colourless to light brown variety in large flakes and masses some times showing alteration into pale green fibrous uralitic hornblende; the feldspars are principally labradorite, and have a strong tendency to idiomorphism, with columnar and occasionally tabular habit; twin lamellation occurs on both the albite and pericline laws, the latter only occasionally, however; a few small crystals of magnetite are



Govt. Photo. Litho.

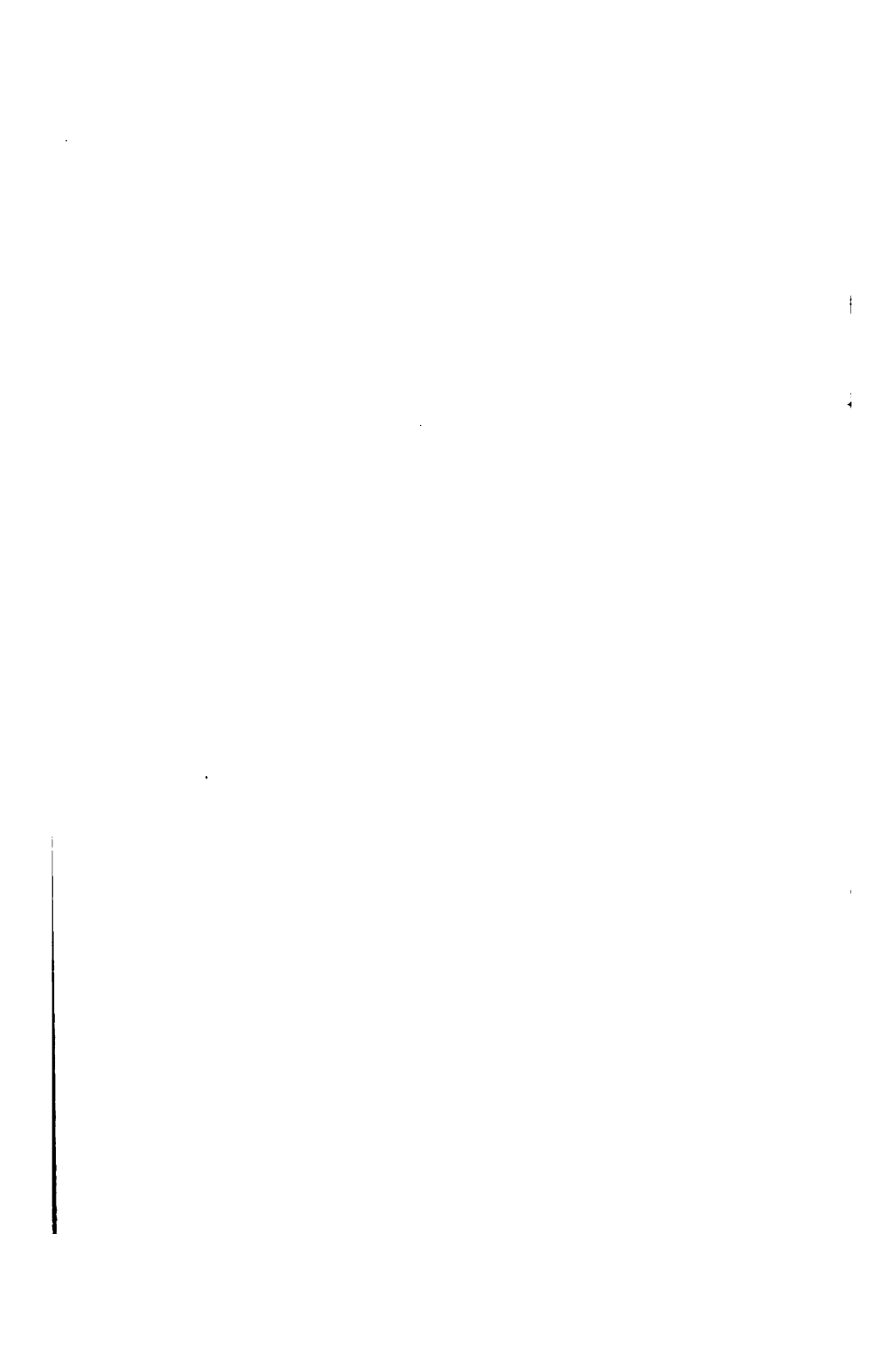
Warren,







Govt. Photo. Litho.  
Warren.



also present. The rock is very little altered and is extremely hard and solid right to the surface, this being characteristic of all the rocks in this district.

Quartz reefs are few and far between, what there are being mostly towards the northern end of the belt, and these are small and of no extent, being merely the infillings of small gashes in the greenstones; the quartz is white and glassy and, judging by the results obtained from dish assays of a large number of samples taken by myself, is extremely low in its gold contents, most of the samples giving blank results, and the best of them only a few dwts.

This belt of country (from Mount Shenton to Mount Venn) is very poorly watered. Three miles from Mount Shenton, on a bearing of 67 degrees from it, is a soak at the north end of a bare granite hill; this, although it was dry at the time of my visit, after an exceptionally dry season, could, after a fair season, be generally depended upon to contain water during the greater part of the year, but the supply would be very limited. Another soak is situated amongst some low granite ridges about 5 miles on a bearing of 132 degrees from Mount Shenton and  $2\frac{1}{2}$  to 3 miles on a bearing of 46 degrees from Mount Grant; as we obtained a small supply of water here, after sinking about twelve feet, this soak may be considered almost permanent, but the supply is small, except after good seasons. These appeared to be the only two soaks of any importance in the locality.

**MOUNT WARREN AND MOUNT CUMMINGS.**—These hills are situated about 30 miles north-east of the Cosmo Newberry Ranges and 90 miles north-east of Laverton. They form the two highest points of a range of hills running about north-west and south-east and occupying an area about five miles in length by three in greatest breadth, and rising to a height of some 200 feet from the sand plains which surround them on all sides, and are known to be continuous from Cosmo Newberry and Mount Shenton to Mount Warren and north and easterly as far as the eye can reach, being only broken by occasional low rough granite ridges. The rocks forming this range of hills consists of fairly coarse-grained greenstone (diorite) and are mostly massive, a little foliation being noticeable on the eastern and north-eastern sides where they come in contact with the main body of granite which underlies the surrounding sand plains.

As far as I was able to ascertain in a brief examination, owing to the scarcity of water, there appear to be no quartz reefs whatever within this area of greenstones, the only reef seen being a large white quartz contact reef along the junction of the greenstones with the granite on the north-eastern side of the hills; this reef is over a chain in width in places and is traceable on the surface for over half-a-mile; so far as tested its gold contents are *nil*.

The locality is badly off for water, there being only one soak in the neighbourhood and that not a particularly good one; during

my visit there, being short of water, we sank on this soak to a depth of about twelve feet but, obtaining only a few pints of water, were compelled to leave it and return to Cosmo Newberry. After a fair season, however, I think this soak could be depended on for a fair supply, but the locality is a good one for prospectors to keep away from.

[The above localities, together with the Ulrich Range, are the only areas of possible auriferous country within the district examined, a district extending from thirty miles or so south of the Cosmo Newberry to as far north as the south end of Lake Wells and easterly to twenty miles beyond Mount Shenton. The whole of this area, with the above exceptions, is occupied by broken granite tablelands and sand plains, the former often being found with weathered vertical cliff faces 50 feet and more in height, locally known as "breakaways"; the sand plains represent the denuded and weathered remains of similar tablelands and occupy by far the greater part of the eastern portion of this State.

## The Ulrich Ranges.

In addition to the localities already described, a short visit was paid to the reported new find at the Ulrich Range on the south-east side of Lake Wells and about 60 miles east-north-east of Duketon, and a report made as to its extent and probable resources.

The workings are situated on the north-eastern side of a low rough ridge of greenstone hills, trending in a general north-west and south-easterly direction for five or six miles, and having a maximum width of a little over a mile, tapering to nothing at either end; these hills are entirely surrounded by sand plains and spinifex. The rocks which comprise this ridge consist of fine to coarse-grained massive and foliated greenstones (amphibolite), similar to those usually found forming the auriferous series of the Eastern fields; these are traversed by a large number of acidic dykes, varying from a coarse-grained granite to a fine, compact, quartz porphyry, the latter type being by far the more prevalent. These dykes vary greatly in size, and run in all directions, though the majority of them have a general north and south trend; they also appear to be newer than the quartz reefs which they frequently cut through; the greenstones are usually considerably crushed and foliated in close proximity to them. The north-eastern fall of the hills is into a long narrow arm of salt lake—probably part of Lake Wells—lying from about two miles away.

This lake runs past the north-western end of the hills, and then turns and runs southerly, being crossed by the road about six miles west of the "find."

The present workings are situated on a small gully running down the eastern fall; this has been worked at irregular intervals for a length of about 20 chains, and a good deal of work has been done. Most of the gold has been got in the wash right in the bed of the creek at a depth of from two to four feet from the surface, and usually at points where the gully is crossed by the granitic dykes which form natural riffles on the bed of the gully. No, or very little, gold has been got on the fall of the hills into the creek; and this fact, viz., that all the gold has been shed and carried into the bed of the creek, militates against the chance of any rich leaders being found. So far most of the gold found is pretty fine, the largest piece obtained being less than 10 dwts. No specimens have been obtained, but one or two pieces of gold were found with small pieces of ironstone attached, which would show that the gold has been shed from a small ironstone leader, or leaders, in the greenstones, which has been completely denuded away. There are several other gullies in the hills, and these have all been tried for alluvial, and so far with negative results; the sides of the hills and the flats at the foot of them have also been tried in numerous places with similar results. At the time of my visit there were seven men at the "find," one of whom was employed in carting water from the soak 20 miles distant by road, the remaining six were engaged in alluvial working, and had obtained amongst the lot of them between 15 and 18 dwts. of gold as the result of a week's work. These men professed themselves as very dissatisfied with the district, and gave it as their intention to leave the place within the next few days. On my way into Duketon I passed another party of five on their way out to the "find"; this will make quite a sufficient number of men to thoroughly test the locality, if that has not been done already.

While at the "find" I saw several runs put through the shakers, and all of them with very disappointing results, mostly only a couple of small "colours." A party of four who were at the "find" some weeks before the present party, obtained 8ozs. 7dwts. of gold as the result of six weeks' work; while, in addition to this, one man got from 28 to 30dwts., but I was unable to ascertain how long it took him to get this amount.

This district was originally prospected by H. Swincer, who is said to have obtained a little alluvial gold here about four years ago; a couple of years later, Kirkpatrick and party, as the result of several weeks' work, obtained a few ounces of alluvial gold; I was unable to ascertain the exact amount, but it was said to be somewhere about 10ozs.

As regards the reefing possibilities of the district, I do not think anything of importance is likely to be found in this line. Quartz reefs are certainly fairly numerous, but they are small and very irregular, being for the most part merely short lenses or gashees running with the foliation of the greenstones, and are, I think, not likely to live to any great depth; they are also much broken and distorted, owing to the intrusions of granitic dykes. The quartz is white and glassy, and, as far as tested, very low in its gold contents; a large number of samples were "dollied" by myself, and the best result obtained was only slightly better than a trace, most of them being blanks. There is, however, one fairly well-defined line of reef—or, rather, line of lenses—traceable on the surface in a north and south direction for a distance of about 10 chains, the largest continuous length of quartz being about 60 feet, and having a maximum width of about three feet; it is, however, broken in several places by granitic intrusions, and the lenses of stone are likely to behave just as irregularly vertically as they do longitudinally.

The stone in this line is the typical white glassy quartz, and near the north end has a considerable quantity of carbonate of copper associated with it, as well as occasional small pockets of galena. This line was carefully sampled by myself, and a large number of samples dollied, the best prospect obtained being equal to about 1 to 2 dwts. per ton. A few of the samples gave traces of gold, but the majority of them were blanks.

Almost every one of these reefs show signs of having been sampled several years back, and the area of possible auriferous country is so restricted that two or three men could thoroughly prospect it, from a reefing point of view, in a couple of weeks, and I am of opinion that this has already been done. The country rock is extremely hard right on the surface, and under existing conditions, *i.e.*, with the nearest battery 60 miles away, and over heavy sand at that, reefs would have to be exceptionally rich to be of any use to the prospectors, and I do not think there are any reefs of this description in the locality; and, in my opinion, even if the reefs were of fair grade, there is nothing of sufficient size or regularity to warrant even the thought of erecting a battery on the spot.

With regard to other possible finds in the vicinity, from personal observations, there is no auriferous country to the south until the Cosmo Newberry Ranges are reached; none south-easterly till Mount Warren—and this is an exceedingly poor belt; and none westerly or south-easterly till the Duketon-Erlistoun belt. To the north and north-east, beyond Lake Wells, low granite ranges and sand plains extend as far as can be seen, and these are said to extend in this direction for practically an unlimited distance.



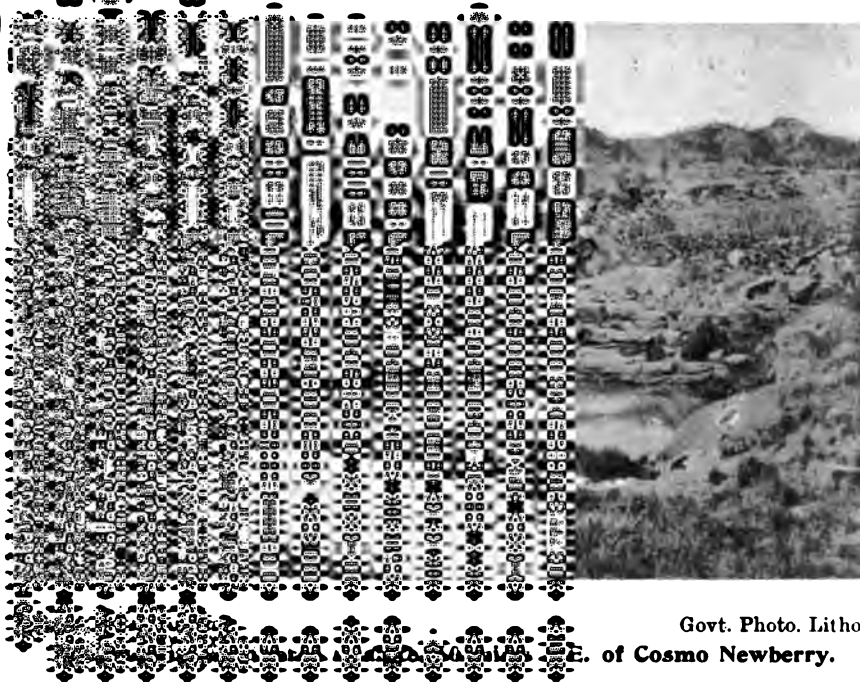
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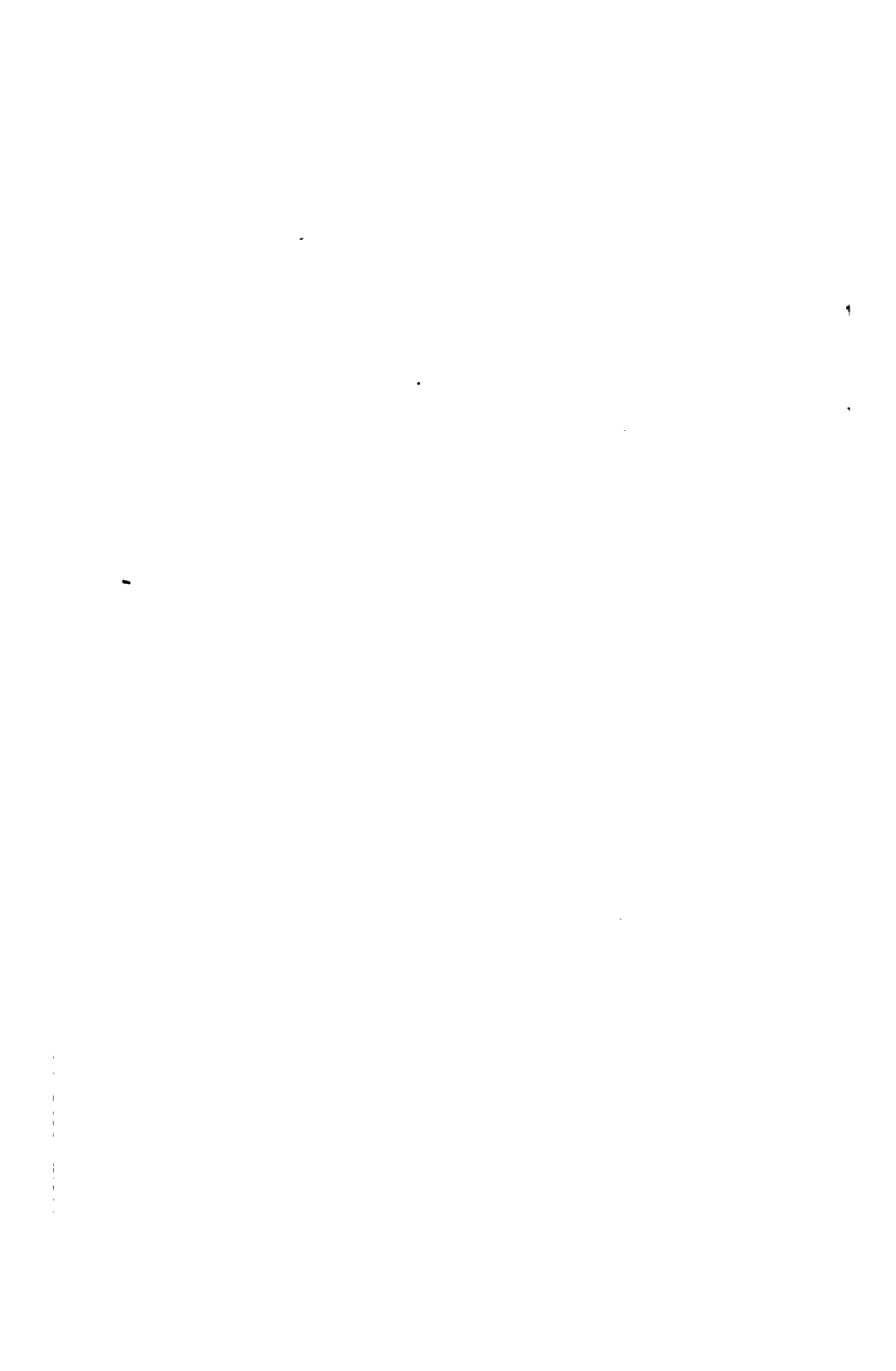


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Govt. Photo. Litho  
of Cosmo Newberry.



As to the water supply of the locality, a well has been sunk on the eastern fall of the hills, about a mile and a-half from the lake, in which water was struck at about 30 feet. This water is, however, too salt to be of use even as stock water. If a well was put down on the other fall, I think the chances are that this would probably be salt too, as the lake runs round this side of the hills as well, though at a somewhat greater distance—about six miles. I do not think a permanent fresh water well is likely to be found in the locality. The present water supply is from a soak in a small creek eighteen direct miles from the “find” along the Duketon road; water has to be carted from here to the “find” over heavy sand, and the supply is only very limited, and unless replenished by rain is not likely to last many more weeks. Between this and Duketon there is no water except at a rock hole six miles from the soak; this, however, is most probably dry by now as there were only a few gallons of water in it early in November.

I am hardly of opinion that the “find” is of sufficient promise to warrant the Government going to the expense of putting down wells along the road, but if these are sunk, almost the only places where they could be put would be (1) on the cork tree flat, 16 miles from Duketon, and (2) on the creek, a little below the present soak, and I am not in great hopes of a supply being obtainable at either place, especially at (1)—that is in shallow wells. If these wells are put down—and this applies to all shallow wells in the out back country—I would very strongly advise that they should be sunk in the summer season, for if a supply is met with, then it can fairly safely be relied upon as permanent, whereas if they are put down in the winter—usually the wet season—a fairly heavy supply of soakage water is often met with which goes dry, or nearly so, before the dry season is over, and this is often a very serious matter in that part of the State. The Cosmo Newberry Government No. 2 Well is a case in point; this well is now only making a few gallons of water per day, and that only after it has been sunk another five or six feet by private parties.

CHAS. G. GIBSON, B.E.

Assistant Geologist.

|      |                                 |    |    |    |                                          |    |          |
|------|---------------------------------|----|----|----|------------------------------------------|----|----------|
| 6545 | Laterite                        | .. | .. | .. | 20 chains east of G.M.L. 1423, Burtville | .. | See page |
| 6546 | Massive greenstone              | .. | .. | .. | Sons of Westralia G.M., Burtville        | .. | See page |
| 6547 | Quartz, coloured with chloropal | .. | .. | .. | Bungarra G.M., Erlistoun                 | .. | See page |
| 6548 | Massive greenstone              | .. | .. | .. | G.M.L. 1444, Erlistoun                   | .. | See page |
| 6549 | Greenstone schist               | .. | .. | .. | 2 1/2 miles S. of Duketon                | .. | See page |
| 6550 | Granitic schist                 | .. | .. | .. | Do.                                      | .. | See page |
| 6551 | Do.                             | .. | .. | .. | Lauriston G.M., Duketon                  | .. | See page |
| 6552 | Do.                             | .. | .. | .. | Mount Maiden                             | .. | See page |
| 6553 | Fine-grained quartzite          | .. | .. | .. | ..                                       | .. | See page |

|      |                         |    |    |                                          |    |            |
|------|-------------------------|----|----|------------------------------------------|----|------------|
| 6554 | Quartz conglomerate     | .. | .. | Mount Maiden                             | .. | See page 7 |
| 6555 | Granite                 | .. | .. | 16 miles N. of Laverton                  | .. |            |
| 6556 | Dyke rock (dolerite)    | .. | .. | 300 feet level, Ida H. G.M., Laverton    | .. |            |
| 6557 | Opaline                 | .. | .. | 400 feet level, Ida H. G.M., Laverton    | .. |            |
| 6558 | Schist                  | .. | .. | 300 feet level, Augusta G.M., Laverton   | .. |            |
| 6559 | Hematite-bearing quartz | .. | .. | Surface, Augusta G.M., Laverton          | .. |            |
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| 6561 | Hematite-bearing schist | .. | .. | 300 feet level, Augusta G.M., Laverton   | .. | See page 7 |
| 6562 | Granite                 | .. | .. | 20 chains west of Augusta G.M., Laverton | .. |            |
| 6563 | Granitic schist         | .. | .. | Cosmo Newberry Ranges                    | .. | See page 7 |
| 6564 | Greenstone schist       | .. | .. | Mount Shenton                            | .. | See page 7 |
| 6565 | Massive greenstone      | .. | .. | 1 mile east of Mount Grant               | .. | See page 7 |
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1906,  
—  
WESTERN AUSTRALIA.

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# GEOLOGICAL SURVEY.

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BULLETIN No. 25.

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## THE PROSPECTS OF OBTAINING ARTESIAN WATER IN THE KIMBERLEY DISTRICT.

BY  
  
R. LOGAN JACK,  
LL.D., F.G.S., F.R.G.S.

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*Issued under the authority of the Hon. H. Gregory, M.L.A.,  
Minister for Mines.*

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WITH A GEOLOGICAL MAP.

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PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

—  
1906.



## PREFATORY NOTE.

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 WING to there being no officer of the Geological Survey Staff available, Dr. Jack was specially commissioned by the Public Works Department to report upon the prospects of obtaining artesian water in the Kimberley Division.

His report, and the explanatory map, on being submitted to the Government, were ordered to be printed for public information, as one of the series of the Geological Survey publications.

The index to names, places, etc., occurring in the report has been prepared by Mr. P. J. Atkins, Clerk of the Geological Survey.

A. GIBB MAITLAND,  
Government Geologist.

Geological Survey Office,  
Perth, 16th July, 1906.





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|----------------|-------------|



## The Prospects of Obtaining Artesian Water in the Kimberley District.

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I beg to report that, in accordance with my instructions, I left Perth and Fremantle on 29th October last and reached Wyndham by sea on 13th November. After making an examination of the neighbourhood of the township, and having completed my arrangements for the journey, I left Wyndham on 20th November, making for Derby overland, by a route determined by the object of the inquiry. Having arrived at Derby on 9th January, I embarked on the 17th and reached Perth on the 27th.

The details of the overland journey are given in the "Itinerary" appended to this Report, and may be followed on sheets 128, to 135, and 141 and 142 of the 300-Chain Map,\* which have been geologically coloured; a reduced map on the scale of 12 miles per inch is attached. The main route amounted to 714 miles, with excursions by buggy, on horseback, or on foot, amounting to about 50 miles more. To the Itinerary there are added notes on the water supply at the camps (43 in number) and at various points along the route. These notes may be of service to future travellers, as they represent the actual condition of things during the severest drought which has yet been experienced by the white settlers of the district. The maps of the Lands Department show numerous "pools" and "springs" which I found dry, and which are not to be relied on except in good seasons.

The "wet season" of 1903-4 had been more or less a failure all over the district, and that of 1905-6 was, at the time of my visit, overdue, so that I saw the country at what it is to be hoped was its very worst. "Dry" camps, to which we had to carry water, had to be made if there was a prospect of feed for the horses. At other camps, we had to "spell" in order to allow the horses to recover from the effects of starvation stages behind, or to fortify themselves for similar stages in front of them. Moreover, as the intense heat (reaching 114 degrees F. and generally well over 100) made it impossible to work the horses between 10 a.m. and 3 p.m. without danger to their lives, valuable time had to be wasted. Under the circumstances, the route aimed at had often to be abandoned in favour of one determined by consideration of grass and water, and visits to certain desirable places had to be abandoned because

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\* Lands Department Lithographs, 1904.

neither of these necessities was to be met with. We were, however, so far fortunate in that we now and then found water from local showers, although these had been either too light or too recent to produce any "spring" in the grass, while in the latter part of the journey rain had fallen long enough before we arrived to make feed abundant, and we suffered little inconvenience beyond an occasional wetting. None of the large rivers which lay across our path had begun to flow.

The main route (which is laid down on the maps) running south-east from Wyndham, touching the Northern Territory south of the 16th parallel, thence proceeding southward on the Western Australian side of the border to 16 degrees 25 minutes south latitude, south-westward to Hall's Creek, the metropolis of the Kimberley Goldfield, and westward and north-westward to Derby, kept, with slight exceptions, within the drainage areas of the two great rivers, the Ord and Fitzroy and their tributaries. The only inhabited places passed on the way were Goose Hill, Ivanhoe, Argyle, Rosewood, and McKellar's Stations, Argyle (Wild Dog) Police Station, Springvale, Texas, Ord River, Nicholson and Flora Valley Stations, Hall's Creek township and telegraph office, Langley's and Fossil Hill Stations, the Fitzroy telegraph office, the Fitzroy Crossing police station and hotel, Oscar Range, Balmaningarra and Meda Stations. Although considerable portions of this track are, as a rule, only used by travellers on horseback, the whole of it may be set down on the map as practicable for vehicles—provided the passengers carry with them a pick, shovel, and axe.

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## Geological Formations.

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- S. Carboniferous Sandstone.
- L. Carboniferous (?) Limestone.
- D. Devonian Sandstone, Grit, and Limestone.
- M. Metamorphic Rocks:—Slates, Schists, Gneisses, etc. (Silurian, Cambro-Silurian or Cambrian).
- G. Granite.
- B. Basalt.

The pioneer geological observer was Mr. Edward T. Hardman, of H.M. Geological Survey of Ireland, who, in 1883 and 1884, accompanied the "Kimberley Survey Expedition," under Mr. Harry F. Johnston, now Surveyor General. Starting within a few days of his arrival in the colony, without any previous acquaintance with

the Australian bush, and practically without maps—since the expedition was only laying the foundation of the excellent topography now available—Mr. Hardman, with a keen eye and intuition amounting to genius, sketched on broad lines the geological features of the district, at the same time pointing out its economic importance. It is true that the Kimberley Goldfield to which he directed attention has not taken, and may never take, a high rank, but his writings attracted the men whose further prospecting has resulted in Western Australia occupying a leading place among gold producers. He wrote two reports (1884 and 1885) "On the Geology of the Kimberley District," accompanied by two geological maps, the first embracing the district from Broome, *via* Derby, to Mount Fairbairn, and the second that from Mount Fairbairn north-eastward to the Northern Territory in latitude 17 degrees south. Although both reports and maps are of extreme value, they bear internal evidence that the printing had not the advantage of the author's supervision.

In 1891, Mr. Harry Page Woodward, then Government Geologist, traversed the country between Wyndham and the Goldfields, his observations supplementing those of Hardman, especially to the north and by a route west of my own, so that geological lines can be extended with confidence.

In 1901, Mr. A. Gibb Maitland, Government Geologist, went out in search of an alleged area of auriferous country between the 15th and 16th degrees of south latitude. No detailed report has yet been issued, but a synopsis is given in the Annual Report of the Geological Survey for 1901. Although Mr. Maitland's travels demonstrated the absence of the expected auriferous region, they were, as will be seen later, of high importance in their bearing on the question of artesian water.

### Carboniferous (S.,L.).

This formation, as understood by Hardman, is divisible into an Upper or Sandstone (S.) and a Lower or Limestone (L.) series. The latter he describes as having been observed by him to be succeeded conformably by the former at the Haughton Range in latitude 19 S. and longitude 127 E. (Second Report, p. 27). All that I have seen is consistent with this order of succession. Hardman does not intend to convey, nor do I, that the Sandstone member consists entirely of sandstone, or the Limestone member of limestone. In the one, however, sandstone and other purely sedimentary rocks prevail, while in the other limestones predominate.

The *Upper or Sandstone series* (S.) was first seen by me at Wyndham and thence northward down the west arm of the estuary which widens out into Cambridge Gulf. It may be regarded as typically developed in the Bastion Ranges, at Wyndham. In these ranges,

which attain a maximum elevation of 1,068 feet, escarpments of sandstone present their steepest faces to the north-west, and dip at a low angle, say seven degrees, to the south-east. Eastward, similar rocks (House Roof Hill, etc.) extend to the border of the Northern Territory. They are divided from rocks which I regard as Devonian by an east and west line running south of Wyndham and the "House Roof Crossing" of the Ord (*see Sheet 142\**). Mr. Maitland informs me that the Wyndham beds extend as a continuous formation westward to the mouth of the Prince Regent River, and have a prevailing dip to the west.

The sandstones themselves are white, although they frequently weather red or yellow, and are sometimes almost hard enough to deserve the name of quartzites. With them are associated shales, which form the bulk of the hills open to observation, although from their softness they are less conspicuous than the sandstones. The shales, so far as my observation goes, are absolutely unaltered, and are of the usual blue, grey, and black Carboniferous type, although they may weather to red or yellow.

In Sheet 141\* only a very small area of the Upper Carboniferous rocks is met with between Mount Brooking and the border of the Northern Territory. Seventy miles farther to the south (Sheet 132\*) the Upper Carboniferous forms the broken tableland of which Mount Elder is the most conspicuous fragment. The tableland lies between the Negri and Ord Rivers, both of which expose the underlying "Limestone" series. West of the Ord, the sandstones extend from the Glass Hill to the Dixon Range, presenting long cliffs surrounded by high "downs."

The formation is next met with at Flora Valley Station, east of Hall's Creek (Sheet 131\*) where the sandstones rise to considerable elevations in Gullana Hill north and Mount Timperley south of the station, and the shales form open "downs."

Granite and Metamorphic and Devonian rocks, all older than Carboniferous, occupy the next 160 miles to the west along my route, and it is not till a few miles below the Fitzroy Crossing that the Upper Carboniferous formation re-appears. Here it is seen in juxtaposition to the Limestone or Lower member of the formation, and there is no reason to doubt that the latter underlies the former, as was observed by Hardman at Mount Abbott to the south-east. The line of demarcation between the two runs to the north-west, along the flanks of the Oscar and Napier Ranges, an enormous area of "pindan" country, diversified by sandstone tablelands, marking the extension of the Upper or Sandstone series of Carboniferous rocks from the George Range to Derby.

The *Lower or Limestone Member* (L.) of the series is not met with north of the Negri River. It occupies the valley of that River

to the east of the Mount Elder Tableland, where it rises into Mount Panton (Northern Territory), and forms high "downs" up the valley of the Ord from its junction with the Negri south-westward to a point about five miles beyond the Hardman Range where it rests on bedded basalts.

From the "Rough Range" (Sheet 130\*) north-westward to the Napier Range (Sheet 134\*) the limestone series attain a most remarkable development. The Oscar Range, as seen from the south-west, shows a rectilinear rampart of limestone, 47 miles in length, which has all the appearance of being the edge of a horizontal tableland. This impression, however, is found, on close inspection, to be erroneous, as the limestone of the rampart is seen to rest unconformably on the slates and schists which compose the core of the range, and to dip to the south-west at 30 degrees. My route in this locality followed the telegraph line, which is carried along the flat at the foot of the "rampart." In this flat the dip of the limestone beds is seen to decrease to 15 and even 10 degrees, and there is every reason to believe that the limestones pass under the sandstones on the south-west side of the telegraph line. In the Geikie, Hull, and Rough Ranges (Sheets 129 and 130\*), the outcrop of the Limestone series is many miles in breadth.

The Sandstone series, according to Hardman (Second Report, p. 25), contain an assemblage of fossils undoubtedly Carboniferous. The list from the Limestone series comprises fossils equally Carboniferous (Loc. cit., p. 26). Mr. H. A. Foord, however, in the *Geological Magazine* for 1900, describes several *Devonian* fossils presented by Hardman to the British Museum before his death. The fossils in question, according to the labels, came from the Rough Range and Mount Pierre, localities from which many of his Carboniferous fossils were derived.

At Minnie Pool (Sheet 130\*), near Mount Pierre, I observed some indication that the limestone region mapped as Carboniferous consists partly of limestones of an older date. At the head of the Pool is a well-bedded limestone dipping to the west at 25 degrees. Between this point and the hill a quarter of a mile to the south, vertical beds of mica schist with a north and south strike are met with. The hill itself is composed of a limestone in beds which dip to the south-east at 80 degrees. Its strong Devonian aspect struck me at once. Some layers were almost entirely composed of corals in very bad preservation, but after a good deal of searching I obtained three specimens which I sent to Mr. Robert Etheridge, Director of the Australian Museum, Sydney. Mr. Etheridge writes that the corals are *Stromatoporoids*, and are, therefore, either Silurian or Devonian, certainly not Carboniferous.

There is always the possibility that Hardman's determinations—apparently made in the field—were less accurate than those of

\* Lands Department Lithographs, 1904.



a palæontological specialist to whom the whole of the literature of the subject and the collections of museums are available. At the same time, I do not question his ability to appreciate the significance of the general *facies* of the assemblage of fossils with which he was dealing. Either there are, in the locality in question, separable Carboniferous and Devonian strata, or the same strata contain a Devonian-Carboniferous, just as certain formations in the Eastern States contain a Carboniferous-Permian fauna. Any fuller discussion of this question would be out of place in a report dealing with the specific question of artesian water, on which it has no practical bearing.

#### Devonian (D).

A formation clearly older, more highly metamorphosed, and more violently contorted than the Carboniferous, and yet neither so much metamorphosed nor so violently contorted as the slates and schists of the Goldfields, was provisionally referred by Hardman to the Devonian. It consists mainly of indurated sandstones, with beds of limestone. The sandstones are frequently so altered by the solution and redeposition of their silica that their original texture is either wholly obliterated or can only be recognised by following lines of coarser or finer grains, and in places may justly be designated "quartzites." Hardman first met with them in the south-western face of the King Leopold Ranges, which he followed from north-west of Mount Broome (Sheet 134\*), south-westward to Mount Huxley and Mount Fairbairn (Sheet 130\*). In this region, my route (in the opposite direction) joined his at Mount Fairbairn, where the sandstones have suffered (so far as I am aware) the extreme of metamorphism in the direction of quartzite. It is not surprising that he should have begun by classing this quartzite as part and parcel of the altered rocks of the Goldfields, and, as a matter of fact, in his first report and first map he did so. Subsequently, however, as he travelled east and north-east, he classed, in his second report, the *same* rock in the Albert Edward Range (where it is less altered) as Devonian. But for the absence of opportunity for revision and his untimely death, he would, in all probability, have altered his first map in accordance with the results of his newer observations.

In my traverse, the Devonian rocks were first met with at Goose Hill, 12 miles from Wyndham (Sheet 142\*), and they occur to the south of a line drawn from that point eastward to the Northern Territory. They form the ranges on the left bank of the Ord River west of the Ivanhoe Stud Station, as far south as the slopes of Mount Hensman (Sheet 141\*), where they abut on, and are evidently divided by, a fault from the "Siluro-Cambrian" slates and schists of the Carr Boyd Ranges. From Mr. Woodward's traverse, we are enabled to extend their area to the Saw and Deception Ranges,

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\* Lands Department Lithographs, 1904.

about 40 miles to the west. On the line of my traverse, they have a general dip to the east at about 30 degrees, while in the Saw Range they are highly contorted and dip to the north-west at 70 degrees. Where I saw them they were hard and quartzite-like on the surface, but when broken presented no very marked appearance of metamorphism.

So far as I could make out from my route, which here took me farther to the east, Mount Brooking and Mount Misery form a Devonian mass on the south-eastern side of the Carr Boyd Ranges. Woodward notes the occurrence of "Devonian Ridges" east of McPhee Creek, at and south of Trig. Station C.N. 8, and in this locality the Devonian rocks apparently rest on granite.

Farther to the south I traced a "wall" of highly inclined limestone from Rosewood Station south-westward to the Behn River, and was informed by Mr. F. C. Hill, of Lissadell Station, that it can be traced south-westward to near Mount Pitt, a total distance of about 45 miles. A similar "wall" runs south-south-west from the "Sugar Springs" for about 10 miles. Both of these masses stand up in the midst of basaltic "downs" precisely as if they were dykes or veins. It would, of course, be absurd to imagine them to be either the one or the other, and I can only suppose that they are "knife-edge" ridges of the old land surface, over the lower denuded portions of which the molten basic lavas were poured.

The Osmond Range, extending for about 40 miles south-west of the Negri River (Sheet 132\*), although I only saw it from a distance, is obviously composed of rocks dipping south-south-east at 30 degrees, and identical with those of the Ivanhoe Stud Station, and I have no hesitation in mapping it as Devonian. It lies between gneisses and schists (Woodward) on the north-west and the Carboniferous rocks (Upper and Lower series) of the Ord Valley. In all probability some of the ranges between Osmond and Turkey Creek are of the same age.

The Albert Edward Range, occupying the left (west) bank of the Elvire River (Sheets 131 and 132\*), and flanked on the west by the slates, schists, etc., of the Goldfield, is composed of grits, sandstones, shales, and limestones. The sandy beds which greatly predominate, are somewhat indurated, but cannot, except occasionally, be spoken of as "quartzites." The strata have a prevailing south-south-westerly dip, varying from 20 to 45 degrees, and frequently coincident with the slope of the eastern side of the range.

The Hardman Range (Sheet 132\*), is composed of rocks identical with those of the Albert Edward, although coloured on Hardman's map as Upper Carboniferous limestone "downs," and is evidently a portion of an old land surface too high to be covered by the deposit of Lower Carboniferous limestone. It is impossible

to explain, otherwise than by hurried observations. Hardman's identification of this range with the Upper Carboniferous. The range is composed of indurated sandstones precisely similar to the rocks of the Albert Edward Range, which he has mapped as Devonian, and absolutely unlike anything which he has mapped elsewhere as Carboniferous.

From the Albert Edward Range westward through the slates of the Hall's Creek Goldfield and the granite which divides the Elvire and Laura drainage basins, nothing more is seen of the Devonian formation. It re-appears, however, in a low range west of the head of the Laura (Sheet 130\*), where it consists of indurated sandstones of the Albert Edward type. Hardman maps it as "quartzites and altered grits" of Lower Silurian or Cambro-Silurian age, and includes Mount Barrett, to the north-east, in the same mass. Although I have only seen Mount Barrett from a distance, it is so obviously different from the indurated sandstones of the head of the Laura that I hesitate to regard it as of the same age.

The Ramsay Range (Sheet 130\*), composed, according to Hardman, of "hard red grits," is mapped by him as Devonian. As seen by me from the north-east it appeared to be identical with the Laura mass, the strata dipping at 20 degrees to the north-west.

Masses of granite, gneiss, and schists intervene between the Laura and Dead Horse Creek (241 mile post of the telegraph line), where the next outcrop of the Devonian rocks is crossed. This place is on the summit of an anticlinal arch, the indurated sandstones dipping to the north to form the Mueller Range and to the south to form low hills which have not been dignified with a name. Farther west, it will be noticed that the indurated sandstones of the Mueller Range, dipping to the north-west, are absolutely continuous with those of the Lubbock Range dipping to the south-east. Hardman has, however, mapped the former as "quartzite and altered grit" of "Silurian or Cambro-Silurian" age, and the latter as Devonian. In his report Hardman insists on the identity of the Mueller Range with the King Leopold Range, with which I entirely agree, in so far as the southern end of the latter (which is all that I have seen) is concerned. In my view, the Lubbock Range and the Mueller Range (and therefore the King Leopold Range) are newer than the "Silurian or Cambro-Silurian" rocks of the Goldfields, and identical with the Albert Edward Range, which I agree with Hardman in calling Devonian.

Mount Bertram, west of the Lubbock Range, consisting of "hard brown grits and flags, with slates and limestones rolling at high angles," is also mapped by Hardman as Devonian.

The gorge of the Margaret River, dividing the Mueller from the King Leopold Range, shows beds of white hardened grits, dipping

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\* Lands Department Lithographs, 1904.

at high angles to the north-west. About ten miles farther, similar sandstones, indurated to the point of being almost quartzites, form a sharp anticline, the strata on the north being part of the King Leopold Range and those on the south being almost immediately faulted against a granitic mass.

Lest it should appear that the above remarks are mainly a criticism of Hardman's report and maps, I should like to make it clear that no one is more fully aware of their value than I am. At the same time I may say that, if I have made corrections, I believe that they are only such as, had Hardman lived to review his completed labours, he would himself have made. The advantage which I had over him in having in my possession fairly reliable maps, while he had practically none, is one which only a field geologist can fully realise.

#### Silurian, Cambro-Silurian, or Cambrian (M).

Large areas of metamorphic rocks, slaty, schistose, and gneissic, were provisionally regarded by Hardman as Lower Silurian or Cambro-Silurian, and in these occur the auriferous veins of the Kimberley Goldfields. There is little physical evidence as to their age, beyond the fact that they are overlaid by Devonian rocks. The palaeontological evidence is also exceedingly meagre, and, scientifically speaking, ought to be ignored, as the two localities from which Hardman collected Cambrian fossils (*Salterella Hardmani* and *Olenellus ? Forresti*), have been defined too vaguely for identification as "Kimberley District" and "River south of Base Line." As the only way in which these rocks affect the question now at issue is that they cover an area in which artesian water is not to be expected, they may be passed over with the mere record of where they occur.

They were first met with by me at Mount Hensman (Sheet 141\*), and it is believed that they form the whole or the greater part of the Carr Boyd Ranges. Next they form a broad belt extending between the granite of the upper waters of the Ord on the north-west and the Devonian and Carboniferous rocks on the south-east, from the Negri River south-westward to, and beyond, the Hall's Creek Goldfield and the McClintock Range (Sheets 132, 131, and 130\*). Isolated patches are met with in the Laura and Margaret valleys (Sheet 130\*), where, at least in some instances, they pass into granites. They then, according to Hardman, form a broad belt extending to the north-west from the Margaret River near Mount Krauss to Mount Amy on the Barker River (Sheets 130, 133, and 134\*). This area, which includes the auriferous rocks of Richenda, is beyond my personal knowledge, with the exception of part of the Oscar Range, where the slates, etc., underlie the Carboniferous (?) limestone.

### Granite (G).

No less "out of it," as regards artesian water possibilities, are the granites which lie mainly west and north-west of my route. According to Woodward and Hardman, an extensive area of this rock stretches from near the junction of McPhee Creek with the Denham River south-westward to the head of the Elvire River, (Sheets 141, 132, 133, 131, and 130\*), a distance of over 150 miles. I crossed the prolongation of this belt west of Hall's Creek on the upper waters of the Laura and Margaret (Sheet 130\*). Further patches were traversed along the telegraph line, west of Dead Horse Creek, and from the gorge of the Margaret, between the Mueller and King Leopold Ranges, to Minnie Pool (Sheet 130\*). In the region thus known to me the granite evidently represents the ultimate stage of metamorphism of the sedimentary "Silurian, Cambro-Silurian or Cambrian" rocks.

### Basaltic Rocks (B).

The western edge of what was designated by Hardman "the Great Antrim Plateau," an area consisting essentially of bedded basic lavas, is mapped by him as extending from a point east of Flora Valley Station (Sheet 131\*), north-eastward to Mount Napier in the Northern Territory (Sheet 132\*). He then brings it, with a sweep to the east, north, and west, back to Western Australia north of the Negri River (Sheet 132\*), and after making it include Mount Close and its vicinity, takes it again into the Northern Territory in lat. 16 degrees 45 minutes south (Sheet 132\*), a little north of the northernmost limit of his journey. Travelling, as I did, from north to south, I first came on the basaltic area at "Pickle Bottle" camp, 16 degrees 4 minutes south (Sheet 141\*), and followed it along the border for 47 miles to the point where Hardman places its northern limit.

From a lithological standpoint, the name "basalt" is not sufficiently comprehensive. Hardman describes the assemblage of volcanic rocks as consisting of "many varieties of basalt, including dolerite and anamesite, trachy-dolerites, lavas, volcanic breccias, and ash beds, ferruginous wackinite, etc.." and it is certain that he has by no means exhausted the list.

As regards its age, Hardman says (2nd report, p. 19): "That it is of intermediate age between the Carboniferous and the supposed Devonian rocks is certain, for within a short distance it is found resting on the one, and covered by the rocks of the other formation, as at the junction (and a few miles below it) of the Pantan and Elvire. At J/38 the limestone is also seen resting on the trap rock." (Sheet 132\*).

My own route lay a few miles above (*i.e.*, south of) the junction of the Pantan and Elvire, and here also I found the basalt emerging

\* Land Department Lithographs, 1904.

from beneath the Carboniferous (?) limestones, and four miles farther west overlying the Devonian sandstones. For nearly 40 miles to the south I saw the Devonian rocks dipping beneath the basalt. The Antrim Plateau, therefore, as far as Hardman saw it, must be approximately on the horizon he ascribes to it. I have, nevertheless, grave doubts whether the almost equally extensive area of basaltic downs (as far as Western Australia is concerned) which I traced from "Pickle Bottle" camp to the right bank of the Negri River is not of much later date. In the latter region, the lava has all the appearance of having simply levelled up a depression formed by the converging Bow and Ord Rivers. If the two basaltic areas are really continuous, I cannot help thinking that there is merely an accidental apposition of two similar masses of widely different ages, the one Devonian and the other probably Tertiary. In what may be called the Argyle area (since the greater part of it is included in the run of that name), the basaltic beds are nearly horizontal and, as far as I can see, overlies the Carboniferous (?) limestone of the Negri Valley. They have covered over the old surface of the Ord River valley with the exception of certain "knife-edge" ridges of Devonian (?) limestone which still protrudes above its level, while other underlying limestone masses (near Argyle Station) have been disclosed by denudation in the bed of the Ord River and its vicinity.

There is some probability that the basalts of this Argyle area were not wholly the result of one continuous period of volcanic activity. Just above what is known as the "Gorge" of the Behn River, between Rosewood Station and Mount Quirk, is a dome or "puy" of basalt, apparently the centre from which issued the lavas that dip away from it to the south-west and north-east. These basalts must have been less fluid than the older beds which form the mass of the Argyle area, since their comparatively rapid solidification has given rise to a thickening in the neighbourhood of the vent and a thinning out as they get farther away, whereas the beds on which they rest appear to have reached, with undiminished fluidity, the limits of the depression into which they were poured.

In a word, I regard the basalts of the Argyle area as probably Tertiary, and as the newest of all the formations represented in the Kimberley district, with the exception of "Pindan" and Recent Alluvium, and possibly the "Upper Tertiary" limestone detected by Hardman on the summit of one of the eminences of the Mount Elder Range.

From the Geological Map accompanying this report, "Alluvium" and "Pindan" have been eliminated. The "Alluvium" is really of very limited area, although Hardman has designated wide regions by the same colour as those "where soils are largely distributed." He had naturally never seen "downs" or the extensive scale on which they are developed from the decomposition of limestones and certain igneous rocks in Australia, and did not realise that they are simply

decomposition products *in situ*. The very large area which he has coloured as "Pindan Gravels and Boulder Beds" marks an instance of the decomposition *in situ* (with the occasional addition of "surface wash") of sandy and gravelly rocks, mainly Upper Carboniferous. "Pindan" it may be explained, is supposed to be an aboriginal word, but is now locally used by the white population to distinguish lightly timbered rolling sandy country. To make "formation" of "pindan" or "downs" merely tends to obscure our conceptions of the actual geological structure.

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## Artesian Water Possibilities.

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### (1.) Wyndham.

The Carboniferous rocks of Wyndham consist principally of dark bluish-grey shales, varying in thickness up to 100 feet. Where these rocks rise into mountain masses, the fact is due to denudation having been arrested by the outcropping of sandstone beds, which are naturally more resistant than the shales. It is usual to refer to the local mountains as "flat-topped" or "sandstone-capped" hills, but the flatness of the strata is only apparent, the rocks, as a matter of fact, generally having a gentle dip. In the immediate vicinity of Wyndham the dip is to the south-east (e.g., in the Bastion Range), although to the eye of an observer placed on the north-west the outcrop of any conspicuous bed appears to be strictly horizontal.

Of the conditions favourable to the existence of artesian matter some of the most important are present at Wyndham.

These are :—

- (1). The occurrence of alternating strata of shale (consolidated clay, to all intents and purposes impermeable) with sandstones (more or less permeable) and
- (2). A dip such as may carry permeable beds from their outcrops in the mountains to not inaccessible depths beneath the places where water is required.

The problem, as regards Wyndham, may be thus formulated. At this port cattle are shipped in large numbers but under conditions of severe hardship. The cattle get no water to drink, as a rule, between the "Twelve-mile" and the steamer. Should any delay occur in shipping, there is nothing for it but to drive the animals back to the water. One instance of a mob having been driven to and from the port for ten consecutive days was related to me.

For the limited human population, rain water and wells, supplemented if necessary, by the distillation of sea water, might suffice, but thousands of cattle cannot thus be provided for.

Something has already been done, or at least attempted, to meet the difficulty, but the experiments have been attended with more expense than success.

Wells have been sunk : (1) behind the Courthouse, (2) behind the Gaol, and (3) in the valley between the West Bastion and Mount Albany.

The court-house well was (on 19th November last) nearly dry. The water was good but the collecting of a bucketful took a long time.

The gaol well (96 feet deep) has a more copious supply (3,000 gallons per day) but the water is too brackish for human consumption, although thirsty horses will drink a little of it. It is said to become distinctly saltier at spring tides. A bore was sunk 594 feet further, but no more water was met with.

From the section given in "Description and Diagrams of Bores for Water and Coal to 30th June, 1900, Public Works Department," it will be seen that shales (sometimes called slates) were almost exclusively met with in the upper half of the bore, while in the lower half "hard grey crystalline sandstone" with slate (shale) bands were the prevailing rocks. In the few fragments of core which I have been able to see the shales are not at all altered, nor are the sandstones extravagantly hard.

The well (Dilyan Springs) in the valley between Mount Bastion and Mount Albany was dry on 16th November. It has been fitted with a windmill which, when there is water, delivers into a service tank at the gaol. The town has also been reticulated with pipes in anticipation of a supply which was not forthcoming.

Two of the conditions upon which artesian water depends may now be discussed, viz. :—(a.) Are there to be found beneath the site of a bore strata which rise to an outcrop on a still more elevated site? and (b.) Are these strata sufficiently open to admit of the passage of water?

- (a.) Assuming a seaside site in Section 82 of the township (selected for reasons afterwards given) and a continuation of the observed rise of the strata (7 deg.) to the north-west, a bore 4,000 feet deep would cut 3,970 feet of strata, among which there is reason to believe some thick beds of sandstone or conglomerate would be met with, such beds rising to their outcrops in the high ground bounded on the east by the west arm of Cambridge Gulf, on the north by the Forrest River, and on the west by the Ernest River.



- (b.) The thick sandstone forming the "cap" of the West Bastion is fairly hard and close-grained, and (the grains of sand having been recemented by dissolved silica) would be described by many, without hesitation, as "quartzite," and the conclusion would be arrived at that it would prove impermeable to water. It is, however, no uncommon experience in tropical countries that sandstones intensely hard and close on the surface prove comparatively soft and open at a depth. As specific instances within my own knowledge may be mentioned the sandstones at Croydon and Montalibion (Queensland). The marked difference in hardness between the Devonian sandstones of the surface and similar sandstones at the depth of 65 feet observed during my journey in a well near Emu Springs is another case in point. My theory on the subject is that the superficial water, being much warmer than in temperate latitudes, dissolves a great deal of silica which, on re-deposition, tends to close up the interstices of the rock, but that this is only a superficial phenomenon.

I was informed by Mr. Cunningham, late postmaster at Wyndham, that the sandstone beds met with in the Gaol bore were in some instances soft enough to be named "sand" by the borers, although the record of the bore makes no mention of such beds. If they actually occurred, the inquiry will be made, "Why, then, did they not carry water?" The explanation may be that these strata crop out under the Gulf, whose muddy bottom prevents their becoming water-conveying channels.

Mr. A. Gibb Maitland, Government Geologist, having travelled extensively in the region west of Wyndham, I felt sure that his observations must have furnished important data on the question of the outcrops of the strata underlying Wyndham. Having been communicated with by telegram, his reply (from Marble Bar, 17th November) was as follows:—

Wyndham beds extend as continuous formation west to mouth of Prince Regent River and from Mt. Hart on Leopold Range north to Admiralty Gulf. Beds have prevailing dip North-West, and comprise quartzite, grits, conglomerates, with interbedded igneous rocks. Am afraid not porous enough.

The south-west dip in the Bastion Range, and the north-west dip observed farther west by Mr. Maitland, point to the existence of an anticlinal arch, which at any rate, must be west of the Ernest River. The south-eastern slope of such an arch would expose, in high country, the outcrops of strata which would pass, and, it may be hoped, carry water, beneath Wyndham.

Mr. H. P. Woodward, then Government Geologist, reporting in 1891 on the "Goldfields of Kimberley District," expressed an

opinion in favour of the prospects of artesian water at Wyndham, although he does not seem to have based his conclusions on any dip of the Carboniferous strata (which, in fact, he refers to as horizontal). His exact words (p. 8) are:—

In the Northern portion of this district (near Wyndham) the rocks are horizontally bedded, the water supply being obtained on the top of, or a little way into, shale beds beneath which the whole subterranean drainage from the interior passes. Therefore, if a bore were put through these beds a large supply would be encountered which would rise to the sea-level, if it did not rise a good height above the surface; in fact this is an artesian area.

In my view, water would rise to the level of the "head of water" (the outcrop of the stratum) or, where the rim of the artesian basin is partly depressed or broken, to the "hydraulic surface," viz., a line drawn from the head of water (intake) to the outlet or leak.

**SITE OF BORE.**—The thick sandstone bed near the summit of Mount Bastion dips, as has been observed, at about 7 degrees to the south-east. As the valley of the West Arm cuts through this stratum obliquely to the strike of the sandstone, the latter is found to the south capping hills at lower elevations. Approximately, its base on the West Bastion is 1,000 feet above sea-level, while at Mount Albany it is only 400 feet.

The gaol well and bore give a section of 690 feet of strata, commencing about 4,000 feet below the horizon of the sandstone. On the site recommended (Section 82 \*) a bore would commence about 1,000 feet below the sandstone, and would thus have 600 feet of an advantage over a bore at the gaol, beginning about 90 feet above where the gaol bore left off.

Even such an apparently small amount as 600 feet may make an important difference when it is considered that 4,000 or 5,000 feet may be taken as the limit of practicable and economical boring.

Mr. Gibb Maitland, in "Report of the Geological Survey for 1902," gives a section of the strata from Mount Albion to the Three-mile. The section of the strata dipping from the former to the latter is pierced, near the Three-mile, by an intrusive mass of basalt, on which he remarks that "any water received on the northern face of the range and percolating down the dips would be checked by this wall of impervious rock, behind which it would tend to accumulate until the water is thrown out by springs." Should such an intrusion of impermeable rock interrupt strata which crop out at high altitudes *west* of the face of the Range, a situation ideally favourable to artesian water would be created, *unless* similar intrusions to the west should be found to *shut off* the water from the supposed strata.

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\* Section 82 of the surveyed township. The existing buildings are on a much less suitable site.

I am of opinion that, although unforeseen difficulties, such as igneous dykes or close-grained rocks, may lead to failure, *all that is ascertainable* gives strong grounds for hoping that a deep bore would meet with success. A successful artesian bore would be the only adequate solution (short of a pumping scheme) of the stock water difficulty which now so seriously retards the progress of Wyndham.

At the same time it would be worth while, before committing the Government to a large expenditure on what is, after all, *a chance* (although in my opinion a good chance) to estimate the cost of a water supply pumped up from the springs at the Gut and conveyed in pipes to the township. The distance as the crow flies is about seven miles.

### **(2.) Country East and North-East of Wyndham.**

In the southern portion of this region (Sheet 142\*) the Ord River has, I believe, a permanent supply of water, serviceable as far as stock can feed back from the frontage.

Should artesian water coming from outcrops far to the west be found at Wyndham, it should be found here also but at greater depths, calculable by the distance and the average dip of seven degrees. I should not advise boring here until after an experiment at Wyndham.

The prospects of artesian water being found at shallow depths would depend on water taken in by the outcrops of local eminences to the west, which are, so far as my knowledge extends, too limited in area to furnish any supply of importance.

### **(3.) Devonian Region between Wyndham and the Carr-Boyd Ranges.**

In this region (Sheets 142 and 141\*) the prevailing rocks are indurated sandstones, frequently approaching the character of quartzites, in beds which are parted by accumulations of shale. My traverse has made me fairly well acquainted with its eastern portion (extending to about 35 miles west of the Northern Territory), but of the western part my knowledge is limited to what has been put on record by Woodward regarding the Saw and Deception Ranges and what I have myself seen of Mount Erskine from the north. Mount Erskine appears to consist of the usual sandstones and shales bent into an anticlinal arch, the strata dipping to north-west and south-east. In the Saw Range, according to Woodward, the dip is to the west, while farther east it is in the opposite direction, so that here also there must be an anticlinal arch. From Goose Hill eastward to the north and south reach of the Ord River opposite Ivanhoe Stud Station the strata dip to the east, or a little to the north of east, at an average of 30 degrees, forming a mass of rugged

\* Lands Department Lithographs, 1904.

hills to the west of the river. These hills rise, I should judge, to about 600 feet above the sea level, on an average, and follow the west or left bank of the river for 20 miles. At one point (H.J.8 on Sheet 142\*) the altitude is given on the map as 958 feet.

The land on the eastern side of the river, except for isolated eminences, is at a much lower level than that on the western, but is evidently formed from similar rocks. I should judge the bulk of it to be not more than 250 feet (the level of Emu Springs). Emu Springs (Sheet 142\*), it may be mentioned, are "well eyes" in a pandanus swamp, and I cannot account for them otherwise than by supposing that the water is brought to the surface by some obstruction such as an igneous dyke concealed by the soil. About  $3\frac{1}{2}$  miles east of the springs I found a party (Torrance and Smith) engaged in sinking a well for the road board. It was down 65 feet, the contract being 85 feet, and no water had, so far, been met with. Although the sinkers called the sandstone "hard," it was soft by comparison with the outcrops of the Devonian beds, and of an open texture favourable enough to the passage or storage of water. The Eight-mile Well,  $5\frac{1}{2}$  miles to the south-east, is sunk 65 feet in sandstone not quite so soft as that of the other. The water is slightly salt but not too much so for drinking purposes. Cockatoo Springs (Sheet 141\*) are similar to Emu Springs, the soil concealing all evidences of the source of the water.

In this region, east of the river (*provided a low site were selected*), I should expect artesian water at no great depth, its source being the elevated outcrops of sandstone extending south from Button's Gap and westward. The only circumstance to cause uneasiness is the supposed hardness of the strata, which seems to be disproved, or at least its probability lessened, by the experience obtained in sinking the wells above referred to.

#### (4.) The "Argyle" Basaltic Area.

This area, or at any rate the Western Australian portion of it (Sheets 141 and 132\*), is fairly well supplied with surface water. The Behn, Ord, and Bow rivers traverse it from south to north, and all, especially the two last-named, have what I believe to be "permanent" water-holes. Again, although I have not seen the locality, there should, if one may judge from the map, be no engineering difficulty in fluming water from the "copious very hot springs" 13 miles west of Lissadell Station to supply a portion of the run. There are, however, portions of considerable extent where grass grows and yet water is too far distant for stock, so that it is possible that artesian water may be among the requirements of the future.

It has already been said that I regard the basalts of this region as having filled up a depression in the neighbourhood of the junction of the Ord and Bow. The surface over which the molten basaltic

lavas were poured out was, no doubt, composed of Devonian and Silurian, or still older, Metamorphic rocks. The Ord and Bow must have been compelled to cut out new channels for themselves after their valleys had been filled up with basalt.

The attitude of the lower edge of the basalt is a factor of high importance in the calculation of the chances of obtaining artesian water, and it is unfortunate that very few data on this subject are available. Presumably the highest point is about the spot where the road from the Wild Dog Police Station crosses it north of the Negri River, and this point may be assumed, from readings in the vicinity, to be about 650 feet above the sea. Argyle Station, by the same aneroid, is 380 feet, and the river at the northern end of the area will therefore be about 300 feet. These readings would, in the distance of 56 miles separating the two points in question, give a fall of 350 feet, or 1 in 845. Supposing the drainage of the high Silurian (or older) land to the south to flow partly underground between the old surface and its present basaltic covering, or to enter any comparatively porous beds of the volcanic series (such as tuffs or scoriaceous lavas), artesian water would be tapped by a bore in any locality where the surface was lower than the intake. It may be argued that a grade of 1 in 845 is very slight for a flow of water, but evidence is not wanting that in spite of the lowness of the grade water *does* flow in or beneath the basalt. Springs rise to the surface at the police station and at the so-called "Sugar" Springs. The water at both places is apparently brought to the surface by the obstruction put in the way of its northward flow by the limestone barrier standing up above the basalt and forming a portion of the old, hard, pre-basaltic surface. It may here be noted that the "Sugar" Springs, five or six in number, rise out of the basalt east of the limestone. They have recently been opened out by the Public Works Department, and the water led into trenches which ultimately direct it into a creek, with the result that a permanent, if limited, supply for travellers and cattle is assured. An attempt was also made to bore for artesian water, but the hand-drills employed were found to be incapable of piercing the basalt to a greater depth than 40 feet.

It might naturally be supposed that the barrier of pre-basaltic land represented by the Rosewood limestone wall would effectually block the flow of underground water to the north-west. But that the flow is *not* blocked is proved by the occurrence of the Stockade Creek "Soda" Springs. These are similar in character to the "Sugar" Springs, although on a larger scale, and make a waterhole nearly a quarter of a mile in length. Nothing is seen to account for the water rising to the surface, but it may be assumed that a barrier of some hard pre-basaltic rock, such as is visible beside the "Sugar" Springs, exists beneath the soil. Limestone, in fact, is seen on the track between the Springs and Argyle Station, not

very far from the Springs. That the underground flow of water is not stopped by the Rosewood " wall," shows that the wall, although coloured on the map (from information supplied) as continuous, must be breached in one or more places—must, in fact, have been cut through by the Ord or its tributaries prior to the out-pouring of the basalt.

Reviewing the whole of the evidence, I am inclined to believe that artesian water may be obtained in any part of the Argyle basaltic area where the surface is not higher than the intake. In view of the insufficient *data* existing regarding altitudes in this region, I should, however, recommend that, before the expense of boring is incurred, levels should be taken between any proposed bore site and some definite and fairly high portion of the " intake," such as the point where the road from the police station to Texas (Kelly's Station) crosses the southern limit of the basalt north of the Negri. The hardness of the basalt must be taken into account in estimating the cost of boring, but I believe that the basalt is of no great thickness—probably less than 300 feet—except in places such as Mount Quirk, Mount Evelyn, Mount Close, and the hills between the 14-mile Creek and Spring Creek.

#### (5.) The Great Antrim Basaltic Plateau.

From the relative altitudes of the eminence J 32 on the top of the plateau (1,661 feet) and the junction of the base of the basalt with the top of the Devonian formation near the Camel Creek Yard (about 1,000 feet), the total thickness of the basaltic beds may be taken to be at least 660 feet. Hardman's estimate (Second Report, p. 18) is 1,126 feet, and it is probable that, as a maximum, this is within the mark. But in questions of boring it is not the maximum thickness deposited, but the minimum to which the formation has been denuded that has to be taken into account. Should the " dip " of the basaltic beds, as seen on the eastern edge of the plateau (about 20 degrees), persist for any distance to the east, the thickness of the basalt would soon be enormously increased, but there is reason to believe that the dip flattens to the east, and, according to Hardman's observations, the beds must swing round to dip beneath the Carboniferous(?) limestone of the Nicholson Valley.

The line along which the Devonian sandstones dip beneath the basalts of the plateau has an approximate elevation above sea-level of from 1,200 feet opposite Flora Valley Station to 800 feet near the junction of the Panton and Elvire Rivers.

The grits and sandstones of the Devonian formation of the Albert Edward Range, dipping to the east and traversed along their strike by the Elvire River, are (unless they are too close-grained, which is more than doubtful) disposed in the most favourable manner conceivable for carrying water beneath the basaltic plateau. The sedimentary Devonian rocks in the west of the Albert Edward

Range, where they abut on the older metamorphic rocks, dip to the east, or south-east, at high angles, but the dip diminishes to the east until, at its junction with the basalt it is not more than 20 degrees, the basalt itself dipping at the same angle. If the basalts are interbedded with the Devonian rocks, or succeed them, so to speak, "conformably," and if we accept Hardman's view that the basalts turn round and dip to the north-west, the Devonian rocks must, not many miles east of the Elvire, flatten out and form a basin beneath the plateau.

No condition more favourable to the existence of artesian water could be imagined, but it must be admitted that there is a good deal of the theoretical about it. I should not advise boring on the plateau until a mass of information, still wanting, has been accumulated with the object of throwing light on the dip and thickness of the basalt. A good many lines might be run from the Elvire across the plateau, and accurately levelled for less than the cost of a single unsuccessful deep bore in hard country.

At the same time anyone who is inclined to "chance it," in a sporting spirit, may have the luck to hit upon comparatively shallow artesian water (probably very limited in amount) derived from the outcrop of some elevated porous volcanic bed within the area of the plateau itself. Personally I should much prefer the compilation of reliable data, followed by logical reasoning.

**(6.) The Carboniferous (?) Limestone Area between the Junction of the Negri and Ord Rivers and the head of the Turner.**

This formation (Sheet 132\*), in which beds of limestone predominate over the sandstone and shale beds, and give rise to extensive "downs" (mapped by Hardman as "Recent"), is seen overlying the basalt between the Hardman Range, and the Elvire River, and, according to Hardman, it bears the same relation to the basalt of the Great Antrim Plateau north-east of the head of the Turner. Its basal beds must, therefore, have an elevation of between 1,000 and 1,200 feet. The greater part of the extensive "downs" between the plateau and the Ord River does not rise above 600 to 800 feet. The strata, which at the south-western and south-eastern boundary of the formation dip to the north-east and north-west, are practically horizontal on the Ord River below its junction with the Elvire, and probably continue to be horizontal where they are covered, on the left bank of the Ord, by the upper or sandstone member of the Carboniferous series until they are faulted against the metamorphic rocks north-west of the Dixon Range. Such a disposition of the strata, supposing some of them to be sufficiently porous, is favourable to the occurrence of artesian water, and become artesian on being released by bores. The success of boring operations will

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\* Lands Department Lithographs, 1904.

depend (1) upon whether or not porous beds occur near the base of the formation, and (2) whether there are water-bearing channels in the limestone itself. As regards the first, all that I can say is that between the Hardman Range and the Elvire River the basal beds are limestone and not sandstone. On the other hand, there are flaggy sandstones in the "downs" between Forrest creek and the Ord River, and there may very well be thick and porous beds in the formation which did not come under my eye. In the alternative case, it is well known that almost every extensive limestone deposit is channelled with underground watercourses. To strike one of these in a bore is, of course, purely a matter of luck.

Failing artesian water in the formation itself, there is a chance of finding it by penetrating the underlying basalts and reaching the Devonian sandstones. To this course it is more than likely that the thickness of the basalts, added to that of the limestone formation itself, will form an insuperable obstacle. At all events it would be well to await definite information as to the thickness of the basalt before making the experiment.

#### **(7.) The Carboniferous Sandstone Area between Glass Hill and the Dixon Range.**

This formation (Sheet 132\*) overlies the Carboniferous (?) limestone, and is extensively developed on the north-western side of the Ord; the Mount Elder Range, on the opposite side, being an outlier of less extent. The prevailing strata consist of white sandstone in horizontal beds, giving rise to tablelands (often denuded to mere fragments) bounded by steep escarpments three or four hundred feet in height. Intervening between these tablelands are extensive sandy "downs" resulting from the degradation of the sandstone. A large area of these "well-grassed plains" has been mapped by Hardman as "Recent."

Naturally no one would dream of boring for artesian water on the fragmentary tablelands; such operations, if attempted, would be confined to the "downs." In the event of the latter being pierced by a bore, the Carboniferous (?) limestone formation would certainly be met with in a few hundreds of feet at the utmost, and the problem before the borer would be precisely the same as that confronting a borer in the limestone formation (*See previous section No. 6.*)

#### **(8.) Flora Valley Carboniferous Sandstone Area.**

It is probable that in the low country, anywhere between Gullana Hill and Mount Timperley, artesian water may be met with at no great depth, either in the Carboniferous sandstone itself or in the underlying Devonian rocks.

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\* Lands Department Lithographs, 1904.



**(9.) The Carboniferous (?) Limestone Area between the Rough and Barker Ranges.**

This large area, trending from south-east to north-west includes the Rough, Hull, Geikie, and Napier Ranges, and a portion of the Oscar Range (Sheets 130, 129, and 134\*). The formation is composed, so far as my observations went, almost exclusively of limestone, with partings of shale. The strata dip to the south-west, at steep angles, away from the granite of the Lower Louisa Valley and the slaty and schistose metamorphic rocks of the ranges to the north-west upon which they rest unconformably. On reaching the plains, the dip becomes less and less steep, and the strata pass beneath the Carboniferous sandstone series.

The country is fairly well supplied with surface water except, perhaps, at the south-eastern extremity, where it attains a breadth of 30 miles, and even there the Fitzroy and Margaret Rivers provide long well-watered frontages. Back from the frontages, however, prolonged droughts such as the one that had barely come to an end when I passed through, give rise to heartrending distress.

I can only repeat what has been already said in dealing with the Limestone Area between the junction of the Negri and Ord Rivers and the head of the Turner (Section 6), that the success of bores in limestone country is a matter of luck, depending on the chances of striking a subterranean water-bearing channel. One such channel, it may be pointed out, is known in the district now under consideration. Near the north-west end of the Oscar Range a creek disappears underground, and has been followed by my informant until it re-emerges half a mile lower. It is certain that, either in such channels or between the limestone and the underlying metamorphic rocks, there must be enormous quantities of water, derived from the drainage of the south-western slope of the Metamorphic ranges. Several springs arise in the limestone near Oscar Range Station.

**(10.) The Carboniferous Sandstone Area south-west of the Oscar and Napier Ranges.**

This area is mainly drained by the Fitzroy and Lennard Rivers. Partly from my own traverse on the way to Derby and partly from Hardman's mapping (the "Pindan" foundation being eliminated), I have coloured with confidence, as included in it, over 12,000 square miles. The whole of this enormous area, with the exception of a number of tablelands, there is good reason to believe, is capable of furnishing artesian water.

The strata, chiefly sandstone and shales, dip to the south-west, where they succeed the limestone on the flanks of the Rough, the Oscar, and the Napier Ranges. In passing to the south-west, however, they soon become to all intents and purposes horizontal,

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\* Lands Department Lithographs, 1904.

and are thus, provided the basal beds of the formation crop out at sufficiently high altitudes, favourably disposed to the existence of artesian water. There is little doubt that the outcrop of the basal bed is high enough. From opposite the Fitzroy telegraph station to opposite the north-west end of the Oscar Range, the elevation of the junction line between sandstone and limestone varies from 500 to 600 feet above sea level, while (except for the tablelands) the general level of the district under consideration can seldom rise above 300 feet.

From Derby to the Fitzroy telegraph station, travellers usually take the circuitous road up the right bank of the Fitzroy, rather than that by the telegraph line, which is nearly direct. On the latter road, there is, in ordinary seasons, a dry stage from the 40 mile to the 92-mile post. When I was travelling in the reverse direction, I was able to follow the telegraph line most of the way, a recent fall of rain having put water in the 57-mile Creek and reduced the dry stage of 52-mile to two stages of 25 and 27 miles. Between the two roads, and south of the Fitzroy, there are broad tracts of country, far removed from water frontages, where abundant grass is useless to stock because of the want of water. In such localities, there is no doubt that artesian water would be of great value, and would immensely increase the cattle-carrying capacity of the pastoral holdings.

It may be well, at this stage, to record such information as has been collected with reference to springs and wells in this region.

### Springs.

Probably the most important of all is the spring south-east of Mount Wynne (Sheet 129\*), which has an estimated flow of 250,000 gallons per 24 hours.

About six miles south-east of the Lower Liverynga, a mud spring is met with. About two miles farther south, five springs break out on a line running north-west and south-east. These springs discharge not only sand but also fishes, which are said to be sightless. A pipe having been driven into one of the springs, the water rose  $3\frac{1}{2}$  feet above the ground.

Eudyella Springs are on the left bank of the Fitzroy, south of Lower Liverynga Station. (Sheet 135\*).

Some springs, about nine miles south-west of the station, give out a stream strong enough to "run" Margaret Creek for six miles.

There are also springs of some importance about 15 miles south of Upper Liverynga, between the Fitzroy River and Mount Arthur. (Sheet 128\*)

The above information is given on the authority of Mr. Percival Rose, general manager for the Kimberley Pastoral Company.

### Wells.

On account of the long dry stage on the telegraph line which has already been referred to, travellers from east to west have to leave the line at Limestone Creek (92 miles from Derby) and make for the site of the old police station on the Lennard—a distance of 30 miles between water and water. A Government well, east of Mount North and north of Mount Percy, breaks up the 30 mile stage into stages of 18 and 12 miles. Beyond the fact that the well has water in it, I was unable to learn any particulars. (Sheet 134\*).

A well, 60 feet in depth, at the Lennard Station has “a little” fresh water.

A shaft was sunk on the telegraph line, at 71 miles 26 chains, to a depth of 100 feet, without meeting any water. So far as I could see the shaft (which had partly fallen in), there was dark carbonaceous shale beneath ten feet of cemented gravel (Hardman’s “pindan” formation).

Two series of wells have been made on Balmaningarra run, and for the information regarding these I am indebted to Mr. J. L. Hutton, the manager. The approximate position of the wells is given on Sheets 134 and 135\*.

The first series was sunk by Wilson and Buck.

No. 1 well (Sheet 145\*) on Mr. M. C. Davies’ Block 330/98, 16 miles east of Derby, is  $102\frac{1}{2}$  feet deep, and has eight feet of water. The last rock turned up by the sinkers, as I saw it in passing, was a very soft, crumbling white grit, well fitted for the retention or passage of water.

Wells Nos. 2 and 4 (Sheet 134\*) are about four miles south of the telegraph line, No. 2 south of the 45, and No. 4 south of the 55-mile post, and No. 3 is in an intermediate position.

No. 2,  $39\frac{1}{2}$  feet deep, with 13 feet 3 inches of water.

No. 3, 61 feet deep. Water in bore at  $36\frac{1}{2}$  feet.

No. 4, 60 feet 10 inches deep. Water struck in bore at 53 feet, rose to 45 feet 10 inches.

The second series was sunk by Foley and Hillier (Sheet 134\*).

Nos. 1 and 2, on the dividing line between Blocks 248/98 and 249/98, were both  $15\frac{1}{2}$  feet in depth, and met with salt water. A report by the Government Analyst gives the proportion of sodium chloride as 1580 grains per gallon in No. 1 and  $577\frac{1}{2}$  grains in No. 2.

No. 3 well, about three miles east of No. 2, struck comparatively fresh water at 35 feet. It stands 19 feet deep, and, according to analysis, has  $288\frac{3}{4}$  grains of sodium chloride per gallon.

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\* Lands Department Lithographs, 1904.

No. 4, about a mile west of the station, is  $28\frac{1}{2}$  feet deep and has three feet of fresh water. The analysis gives only 79.3 grains of sodium chloride per gallon.

No. 5, three miles north-east of station, has a depth of 42 feet. Fresh water was met with at 28 feet and rose 12 inches.

#### Upper Liverynga Bores.

Two bores on this run, as I am informed by Mr. Rose, have actually struck artesian water at shallow depths.

One, about three miles north-east of Mount Wynne, has a flow of 7,000 gallons per 24 hours. I could not ascertain the precise depth of the bore (Sheet 134\*).

The other, about three miles north-east of the station (Sheet 135\*), is 70 feet deep, and discharges 1,500 gallons per 24 hours. A  $1\frac{1}{2}$ -in. pipe having been cemented in, the water rises 12 inches above the surface.

#### Yeeda Wells.

The information regarding these wells is given on the authority of Mr. T. Galbraith, the manager. Their position (east of the Yeeda River) is marked on Sheet 135\*.

No. 1, 40 feet deep; in sandstone; seven feet of water.

No. 2, 35 feet deep; in sandstone; seven feet of water, which comes from a hole in bottom, and *pulsates*.

No. 3, 28 feet deep; in sandstone and ironstone; five feet of water.

No. 4, 80 feet deep; in sandstone; eight feet of water; supply too large to be baled out.

No. 5, 95 feet deep; in sandstone; 20 feet of water.

No. 6, in progress.

#### Wells between Meda Station and Derby.

A well was sunk by the Road Board, about  $1\frac{1}{2}$  miles west of Wilson and Buck's No. 1 well, to a depth of 70 feet, without success. (Sheet 135\*).

At Gooda Gooda, on the edge of the swamp, about seven miles east of Derby, a well (Sheet 135\*), just above high water mark, has a copious supply of fresh water at a depth of about 12 feet.

Mayalli Well, about three miles south-east of Derby, is 30 feet deep, and has about six feet of somewhat brackish "stock" water. It has a windmill and a hot air pump, a tank of a capacity of 25,000 gallons, and troughing. As regards the supply, I was informed

that it has watered 1,000 head of cattle continuously for a week. Reckoning 10 gallons of water per head daily, this would amount in a week to 70,000 gallons.

### Wells in Derby.

These wells, which are too close together to be shown on the 300 chain map, are located on the six chain plan of the "Townsite of Derby," 1896.

The Town and Jetty Supply Well is in the north-west corner of the Hamersley Square. I visited it and obtained from Mr. Armistage, of the Water Supply Department, the following particulars:—

The water is pumped by a windmill to elevated tanks and delivered by pipes to the town and jetty. A gas engine is about to be installed, and a new reticulation has been commenced. A shaft was first sunk to the depth of 35 feet, the section showing three feet of sand, four feet of gravel, and 28 feet of "rock." Water was struck in "pipe-clay" (decomposed shale), in a bore which was carried down to 50 feet. The water rose in the bore, which, however, was plugged up, and the shaft was sunk to a total depth of 48 feet. The water then rose to 20 feet from the surface, a level which it has since maintained.

The supply has, at times, not been equal to the demand, but this is attributed not to the well but to the windmill.

The private wells in the town were gauged during my stay in Derby, with the guidance and assistance of Mr. McGovern, one of the oldest and most enterprising residents.

*In Allotment 42.*—Well 26 ft. 8 ins. deep. Bored to 52 ft. 8 ins. through "pipe-clay" to water-bearing bed, when the water rose in an hour to 15 feet from surface. Water now standing 15 ft. 3 ins. from surface.

*In Allotment 43.*—Depth 31 feet; 16 feet 3 inches of water standing.

*In Allotment 84.*—Depth, 21 feet 4 inches. Water now standing 18½ feet from surface.

*In Allotment 45.*—Depth, 31 feet 9 inches. Water now standing 14 feet 4 inches from surface.

*In Allotment 76.*—Depth, 32 feet 4 inches. Water now standing 17 feet 3 inches from surface.

*In Chinese Garden.*—(Allotment 72) (?).—Depth, 39 feet 9 inches. Water now standing 25 feet 1 inch from surface.

*In Forrest Street, opposite Allotment No. 1.—Shallow ; surface soak only.*

*In Delaware Street, opposite Allotment No. 54 :—Shallow ; surface soak only.*

### **Observations on Wells and Bores in Area 9.**

The sub-artesian character of a large number of the wells is very significant. That water, when met with in a well or bore, should rise for some distance, even if it comes short of the surface, proves that the water is conveyed in a stratum of rock which rises to the surface at an altitude at least as high as that to which it rises in the well or bore when the impervious bed overlying it has been pierced.

*The sub-artesian water would have been artesian water if the surface had been lower.* If we take, for instance, a site 100 feet above sea-level, and, on boring to 50 feet, strike water which rises to 40 feet, or to 90 feet above sea-level, we have missed artesian water by only ten feet. In other words, if the surface had been 90 feet or say 89 feet, above sea-level, we should have had an artesian supply. This shows the necessity of *selecting low sites* for bores, except, of course, in areas where the underground water-level is already well known. In the hypothetical case we have used as an illustration, the water-bearing stratum must rise to the surface at a higher level than the surface of the bore, but had the bore been carried deeper into the same formation, it is highly probable that further water-bearing strata rising to more distant and more elevated outcrops would have been met with, triumphantly realising the desired object, viz. : artesian water.

It cannot be too strongly insisted upon that two artesian bores (at Liverynga) have already been sunk in the district. Although these bores are on a small scale, they, and numerous sub-artesian wells and bores, prove that artesian water is no longer a matter of theory.

The delay of my steamer for a few hours at Broome enabled me to visit, with Mr. Armitage, the town and jetty supply wells in that township. They are situated near the English Church, at the foot of a ridge of blown sand, and about 44 feet above sea-level.

The three wells from which the supply is pumped for the town and jetty are all between 10 and 11 feet in depth, and yield a copious supply of fresh water. One of them, however, was sunk a foot farther and got into salt water.

In the same enclosure, a bore is in progress in search of artesian water. The following notes on samples of strata from various depths may be of interest, as showing the nature of the rocks met with

in nearly 500 feet of boring through Carboniferous rocks—the same formation as that at Derby (Area 9):—

|                                                                                                  |         |
|--------------------------------------------------------------------------------------------------|---------|
| Fine red sand, from surface to                                                                   | 30 feet |
| Red sandstone, thence to                                                                         | 46 "    |
| Fine white argillaceous and siliceous sandstone, thence to                                       | 68 "    |
| Fine siliceous sandstone, purely coherent, thence to                                             | 80 "    |
| Fine siliceous sandstone, thence to                                                              | 88 "    |
| Fine siliceous sandstone, less coherent, thence to                                               | 103 "   |
| Fine siliceous sand with mica, thence to                                                         | 210 "   |
| Unconsolidated siliceous grit (grains size of No. 1 shot), with salt water, thence to            | 220 "   |
| Fine white siliceous sand (core), thence to                                                      | 282 "   |
| Fine red siliceous sand, thence to                                                               | 290 "   |
| Coarse, friable siliceous, felspathic grit (grains size of swan shot) with salt water, thence to | 310 "   |
| Fine white siliceous sand (core), thence to                                                      | 340 "   |
| Unconsolidated siliceous grit (grains size of No. 1 shot) with salt water (core), thence to      | 345 "   |
| Fine white siliceous and micaceous sand (core), thence to                                        | 388 "   |
| Fine yellow siliceous grit, thence to                                                            | 445 "   |
| Fine siliceous sand, thence to                                                                   | 451 "   |
| Grey sandstone, thence to                                                                        | 466 "   |
| Coarse grit or fine conglomerate, with salt water, thence to                                     | 468 "   |
| Coarse siliceous grit, thence to                                                                 | 478 "   |

Salt water was standing at 20 feet from the surface.

A record of the strata passed through in the bore at Pelican Hill, Carnarvon, will be found in the Annual Reports of the Geological Survey for the years 1902 and 1903. The bore was carried to a depth of 3,011 feet. The result is thus summed up by Mr. Gibb Maitland:—"At a depth of 2,611 feet the supply of artesian water yielded 300,000 gallons per diem, and at 3,011 feet the supply was 520,000 gallons." When it is remembered that the strata at Carnarvon are Carboniferous, that is, of the same age as those of Derby, there is the less reason to fear that the latter will prove too hard or too close in grain to carry water. As the strata in the Derby district, so far as the evidence goes, present the remaining conditions necessary to the presence of artesian water, there need be no hesitation in making the experiment.

#### Concluding Remarks.

My special thanks are due to Mr. Armitage, of the Water Supply Department, for much valuable information; to Dr. Maloney, Resident Magistrate, Wyndham, and Dr. MacQueen, Resident Magistrate, Derby, for placing many facilities at my disposal; to Mr. W. E. Cooke, Government Astronomer, for a careful reduction of my aneroid readings; and to Mr. J. J. Butler, of Wyndham, who supplied horses and saw me successfully through the many difficulties placed in the way by a drought of unprecedented severity.

In the matter of aneroid altitudes, it may be said that the aneroid I carried appears to have, as a rule, given too high results. For example, my reading at Hall's Creek was 1,400 feet, whereas the

correct altitude is more likely to be 1,225 feet, the average of numerous barometrical readings. In spite of this, however, my readings (allowing for atmospheric disturbances) are at least approximately proportional, so that, in speaking of the comparative altitudes of different localities, the validity of the argument is not affected by the error.

In the preceding pages the geological sketch may be tedious to many readers, but it was necessary to show the grounds on which I arrived at my conclusions. The subject has by no means been exhausted, although its further discussion had better, perhaps, be reserved for the pages of a geological journal.

In the latter part of the report I have passed in review nine distinct areas (defined on the map) in which, according to my lights, I anticipate more or less success in the search for artesian water, and have discussed each of them on its own merits. However the financial questions involved may be adjusted between the Government and the pastoral lessees, I entertain no doubt that artesian water is destined to play an important part in the future of the pastoral industry of the Kimberley District.

R. LOGAN JACK.

Surrey Chambers, Perth, 27th February, 1906.



## APPENDIX.

## Itinerary and Notes on Water.

|                                                                                                        | Sheet of<br>300 ch.<br>Map.* | Miles. | Notes.                                                            |
|--------------------------------------------------------------------------------------------------------|------------------------------|--------|-------------------------------------------------------------------|
| Wyndham to Parry's Lagoon ...                                                                          | 142                          | 15     | Permanent water.                                                  |
| Parry's Lagoon to Pear Tree Camp                                                                       | "                            | 15½    |                                                                   |
| Pear Tree to "Bend of Ord River"<br>(House Roof Crossing)                                              | "                            | 2½     | Permanent water above<br>crossing.                                |
| Pear Tree to Ivanhoe Stud Station                                                                      | "                            | 17     | Well.                                                             |
| Ivanhoe to Emu Springs ...                                                                             | "                            | 18     | Permanency of water<br>doubtful.                                  |
| Emu Springs to Torrance & Smith's<br>Well                                                              | "                            | 3½     | In progress; no water<br>yet at 65ft.                             |
| Torrance and Smith's to 8-Mile Well                                                                    | "                            | 5½     |                                                                   |
| 8-Mile Well to Cockatoo Springs ...                                                                    | 141                          | 8      | Permanent water.                                                  |
| Cockatoo Springs to Golden Gate...                                                                     | "                            | 3      | Waterholes were nearly<br>dry, but replenished<br>by recent rain. |
| Golden Gate to Pickle Bottle Creek                                                                     | "                            | 8      | Permanency of water<br>doubtful.                                  |
| Pickle Bottle Creek to Hicks' Creek                                                                    | "                            | 11     | Dry.                                                              |
| Hicks' Creek to Argyle Downs<br>Station                                                                | "                            | 11     |                                                                   |
| (Argyle Downs to Stockade Creek,<br>Soda Springs and back, 10 miles)                                   | ...                          | ...    | Permanent water.                                                  |
| Argyle Downs to Behn River, last<br>crossing                                                           | "                            | 25     | Permanent water.                                                  |
| (Behn River to Rosewood Downs<br>Station, Northern Territory, and<br>back, 20 miles)                   | ...                          | ...    | Well and water in<br>Stockade Creek.                              |
| Behn River to Sugar Springs (bores)                                                                    | "                            | 4      | Permanent water.                                                  |
| Sugar Springs to Argyle Police<br>Station (locally "Wild Dog")                                         | "                            | 12     | Permanent water.                                                  |
| Argyle Police Station to Spring<br>Creek (near Spring Vale Station)                                    | "                            | 6      | Permanency of water<br>doubtful.                                  |
| Spring Creek to 14-Mile Creek ...                                                                      | "                            | 7      | Permanent water.                                                  |
| 14-Mile Creek to 9-Mile Creek ...                                                                      | "                            | 7      | Water from recent rain.                                           |
| 9-Mile Creek to Negri River ...                                                                        | 132                          | 9      | Permanent water.                                                  |
| Negri River to Ord River, Camp 12                                                                      | "                            | 5      | Permanent water.                                                  |
| (Camp 12 to Texas Station, 2 miles;<br>well to Salt Springs in Ord River,<br>2 miles and back—8 miles) | ...                          | ...    | Permanent water.                                                  |
| Camp 12 to White Mountain Creek                                                                        | "                            | 14     | Water doubtful.                                                   |
| White Mountain Creek to Kelly's<br>Creek                                                               | "                            | 3      | Water from recent<br>rain.                                        |
| Kelly's Creek to Ord River Station<br>(Forrest Creek)                                                  | 132                          | 7      | Wells.                                                            |
| Ord River Station to Gully ...                                                                         | "                            | 8      | Water from recent rain.                                           |
| Gully to "The Brook," tributary of<br>Linacres River                                                   | "                            | 7      | Permanent water.                                                  |

\* Lands Department Lithographs, 1904.

ITINERARY AND NOTES ON WATER—*continued.*

|                                                                                    | Sheet of<br>300 ch.<br>Map.* | Miles. | Notes.                                                                      |
|------------------------------------------------------------------------------------|------------------------------|--------|-----------------------------------------------------------------------------|
| "The Brook" to Nicholson River,<br>first crossing                                  | 142                          | 6      | Dry.                                                                        |
| First to second crossing of Nicholson                                              | "                            | 5      | Dry.                                                                        |
| Second crossing to Nicholson hut ...                                               | "                            | 6      | Permanent water.                                                            |
| Nicholson hut to last crossing of<br>Nicholson                                     | "                            | 5      | Permanent water.                                                            |
| Nicholson River to Gap in Hardman<br>Range                                         | "                            | 15     |                                                                             |
| Hardman Range to Turner River                                                      | "                            | 2      | Permanent water for<br>digging.                                             |
| Down Turner River to Crossing ...                                                  | "                            | 1½     |                                                                             |
| Turner River to Gap in Basalt<br>Range                                             | "                            | 4½     |                                                                             |
| Gap to Springs ... ..                                                              | "                            | 2      | Permanent water (?)                                                         |
| Springs to Coogeebrin ruined sta-<br>tion, Elvire River                            | "                            | 6      | Permanent water.                                                            |
| Coogeebrin to Camel Creek Yard ...                                                 | "                            | 8      | Permanency of water<br>doubtful.                                            |
| Camel Creek Yard to Camp 18 ...                                                    | 131                          | 7      | Dry.                                                                        |
| Camp 18 to J 48, Elvire River ...                                                  | "                            | 8      | Permanent water.                                                            |
| J 48 to Flora Valley Station, Elvire<br>River                                      | "                            | 18     | Wells.                                                                      |
| Flora Valley to Mud Springs ...                                                    | "                            | 15     | Permanent water.                                                            |
| Mud Springs to Palm Springs, near<br>Black Elvire River                            | "                            | 3      | Permanent water.                                                            |
| Palm Springs to Hall's Creek Tele-<br>graph Station                                | "                            | 20     | Wells.                                                                      |
| Telegraph Station to Head of Hall's<br>Creek, Camp 22                              | 130                          | 5      | No permanent water.                                                         |
| Camp 22 to Rockhole Pool (Langley's<br>Sheep Station)                              | "                            | 12     | Permanent water.                                                            |
| Rockhole Pool to Claypan ... ..                                                    | "                            | 10     | Water from recent rain.                                                     |
| Claypan to Tailers' Camp ... ..                                                    | "                            | 2      | Water from recent rain.                                                     |
| Tailers' Camp to Laura Billabong                                                   | "                            | 4      | Water from recent rain.                                                     |
| Laura Billabong to Claypans at<br>267-mile Telegraph Pole                          | "                            | 12     | Water from recent rain.                                                     |
| Claypans to Margaret River ... ..                                                  | "                            | 7      | Dry; water from recent<br>rain.                                             |
| Margaret River to Soda Springs ...                                                 | "                            | 12     | No water—Water in<br>bed of creek (dig)<br>about 251½ telegraph<br>mileage. |
| Soda Springs to Gully, between 245<br>and 250 miles                                | "                            | 5      | Dry.                                                                        |
| Gully to Dead Horse Creek, at 240<br>miles                                         | "                            | 8      | Water for digging.                                                          |
| Dead Horse Creek to Spinifex Flat—<br>Camp No. 27, near 233 Telegraph<br>Mile Pole | "                            | 9      | Dry.                                                                        |
| Camp 27 to Margaret River ... ..                                                   | "                            | 15     | Nearly dry—water for<br>digging                                             |

\* Lands Department Lithographs, 1904.

ITINERARY AND NOTES ON WATER—*continued.*

|                                                               | Sheet of<br>300 ch.<br>Map.* | Miles. | Notes.                                                                                  |
|---------------------------------------------------------------|------------------------------|--------|-----------------------------------------------------------------------------------------|
| Margaret River to Spring Creek ...                            | 130                          | 2      | Water from recent rains.                                                                |
| Spring Creek to Camp 28 ...                                   | "                            | 1      | Dry.                                                                                    |
| Camp 28 to Pont's Creek ("F 140" Creek)                       | "                            | 2      | Water up creek.                                                                         |
| Pont's Creek to Morgan's Grave ... (Res. 1580)                | "                            | 15     | Water.                                                                                  |
| Morgan's Grave to Mount Fairbairn                             | "                            | 2      |                                                                                         |
| Mount Fairbairn to Camp 29, near Telegraph Pole 198 mile      | "                            | 2      | Dry.                                                                                    |
| Camp 29 to Rockhole on Louisa River                           | "                            | 8      | Dig for water in sand.                                                                  |
| Rockhole to Louisa Crossing ...                               | "                            | 1½     |                                                                                         |
| Louisa Crossing to Camp 30 on Margaret River, near Black Rock | "                            | 7½     | Permanent water in river.                                                               |
| Camp 30 to Minnie Pool ...                                    | "                            | 6      | Permanent water.                                                                        |
| Minnie Pool to Camp 31 on Margaret River, near Mt. Pierre     | 129                          | 12     | Permanent water.                                                                        |
| Camp 31 to McDonald's Crossing of Margaret River              | "                            | 8      | Permanent water.                                                                        |
| McDonald's Crossing to Fitzroy Telegraph Station              | "                            | 14     | Well.                                                                                   |
| Fitzroy Telegraph Station to Fitzroy Crossing                 | "                            | 6      | Permanent water.                                                                        |
| Fitzroy Crossing to Brooking Creek Hotel                      | "                            | 1      | Permanent water.                                                                        |
| Hotel to Oscar Range Station ...                              | 134                          | 14     | Permanent water.                                                                        |
| Oscar Range Station to "6-mile Well"                          | "                            | 8      | Water.                                                                                  |
| "6-mile Well" to "120-mile Creek"                             | "                            | 5      | Permanent water.                                                                        |
| 120-mile Creek to 117-mile Pool ...                           | "                            | 3      | Water from recent rain.                                                                 |
| 117-mile Pool to 107-mile Creek ...                           | "                            | 10     | Running water—recent rain                                                               |
| 107-mile Creek to 100-mile Fence...                           | "                            | 7      | Pool from recent rain.                                                                  |
| 100-mile Fence to Limestone Creek                             | "                            | 8      | Water scarce; said to be four or five more miles up creek.                              |
| Limestone Creek (92-mile) to 67-mile Creek                    | "                            | 25     | Running water from recent rain, but usually dry. Tanks erected for telegraph repairers. |

NOTE.—There is usually no water between Limestone Creek and the "Corner Billabong" (May River). Travellers in ordinary weather must leave the telegraph line at Limestone Creek, and go *via* Mt. Percy and Mt. North (Government Well between the Lennard River, and Balmaningarra Station, rejoining the telegraph line about the 36 mile pole. Distance, approx. 72 miles.

ITINERARY AND NOTES ON WATER—*continued.*

|                                                                                                      | Sheet of<br>300 ch.<br>Map.* | Miles. | Notes.                       |
|------------------------------------------------------------------------------------------------------|------------------------------|--------|------------------------------|
| 67-mile Creek to 56-mile Pole ...                                                                    | "                            | 11     | Water from recent rain.      |
| 56-mile Pole, North, across Plain (no<br>track) to Creek outside of Bal-<br>maningarra Sheep Paddock | "                            | 6      | Permanent water.             |
| Creek to Balmaningarra Station ...                                                                   | "                            | 8      | Permanent water.             |
| Balmaningarra Station to Yard on<br>May River                                                        | "                            | 4      | Running from recent<br>rain. |
| Yard to "Corner Billabong" ...                                                                       | 135                          | 5      | Permanent water.             |
| "Corner Billabong" to 36-mile Tele-<br>graph Pole                                                    | "                            | 8      | Water from recent<br>rain.   |
| 36-mile Pole to Emanuel's Yard ...                                                                   | "                            | 3      |                              |
| Yard to Meda Station ... ..                                                                          | "                            | 9      | Permanent water.             |
| Meda to Open Well ... ..                                                                             | "                            | 10     |                              |
| Well to Gooda Gooda ... ..                                                                           | "                            | 10     | Well.                        |
| Gooda Gooda to Derby ... ..                                                                          | "                            | 7      | Wells.                       |
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\* Lands Department Lithographs, 1904.



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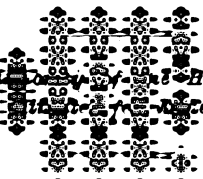
1870-71 SURVEY.



THE PORTS,



Gregory, M.L.A.,



FIGURES.



GOVERNMENT PRINTER.





## PREFATORY NOTE.

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This Bulletin includes a series of miscellaneous reports by various members of the staff, which in themselves are not sufficiently large to warrant issue as separate publications.

These reports have not been published in the official records of the State (though most of them appeared in the local press) and the issue of them in a collective form will, it is hoped, serve to make known the varied mineral and allied resources of Western Australia.

A. GIBB MAITLAND,  
Government Geologist.

Geological Survey Office,  
Perth, 18th March, 1907.

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## 1.—Possibility of the Occurrence of Artesian Water in the Northampton and Geraldine Districts.

(With a Map.)

The consideration of the question as to whether the pastoral lands lying "beyond Geraldton, North of Northampton" are capable of yielding artesian water is very much a matter of geological investigation and mapping.

It is not clear to what special portion of the Murchison District the motion brought forward in Parliament, on the 6th of December last, refers. This motion reads :—

Whether in view of the fact that the carrying capacity of the great wool-producing centre beyond Geraldine, north of Northampton, would be very much increased if there was an ample and certain water supply, the Government would be prepared at an early date to bore in that district for the purpose of testing whether artesian water existed there or not.

In the year 1897 a traverse was made of the country between Northampton and Peak Hill (a), and an examination, in more or less detail, was made of the valley of the Murchison River as far as the big bend at Bompas Hill. Later on, in the year 1900, I traversed the country between Cue and Carnarvon, in connection with the question of artesian water (b), and in the early part of 1901 returned from Carnarvon to Northampton along the telegraph line.

These traverses, coupled with the information contained in the different official reports by my predecessors, together with the records of the bores put down during the last few years, afford ample data for dealing with the broader aspects of the question without a special visit to the district being necessary.

Since the date of my report of December 17th, 1896 (c), some boring has been carried out in the Champion Bay District, having the search for artesian water for its object. Two of these bores, viz., Dongara (d) and Yardarino (e), have been successful in obtaining overflowing supplies; the Geraldton Racecourse Bore (f), a sub-artesian supply, whilst the Geraldton Station Yard Bore (g), having reached bedrock at 420ft., obtained no water.

- 
- (a) Annual Progress Report of the Geological Survey for the year, 1897.  
Perth : By Authority, 1898, pp. 14-19.
  - (b) Annual Progress Report of the Geological Survey for the year 1900.  
Perth : By Authority, 1901, pp. 26-28.
  - (c) Annual Progress Report of the Geological Survey for the year 1896. *Vide*  
Annual Report Department of Mines for the year 1896. Perth : By Authority,  
1897, p. 28.
  - (d) The Mineral Wealth of Western Australia. Geological Survey Bulletin No. 4.  
Perth : By Authority, 1900, pp. 105-106.
  - (e) Annual Progress Report of the Geological Survey for the year 1901.  
Perth : By Authority, 1902, pp. 13-14.
  - (f) The Mineral Wealth of Western Australia. Geological Survey Bulletin No. 4.  
Perth : By Authority, 1900, pp. 140-141.
  - (g) Loc. Cit. p. 139.

The bore at Pelican Hill (a), Carnarvon, which had been carried down to a depth of 3,011ft., obtained an overflowing supply of water at the rate of 520,000 gallons per diem. The record of this bore shows in descending order :—About 150ft. of newer or post-tertiary strata; about 1,211ft. of mesozoic (and possibly cretaceous) rocks; and about 1,650ft. of carboniferous rocks; the base of the latter formation, however, was not reached.

The important point in this bore is the fact that the main artesian supply is drawn from the bed of sandstone, 448ft. in thickness, which forms the lowest bed of the carboniferous series penetrated.

These strata cross the Gascoyne River and extend without any interruption southwards to the valley of the Wooramel somewhere between Innouendy and Bilung Pools (b). At the former place granitic rocks prevail, whilst in the vicinity of the latter, sandstones, shales, and conglomerates, dipping south-west at a low angle, occupy the country. The pebbles in the conglomerate are of rocks identical with those which form the Coor-de-Wandy, Yalbra, and similar hills.

Near the mouth of the Wooramel River there are, in addition to the coastal limestone, fossiliferous tertiary rocks, and the mesozoic beds, from beneath which the carboniferous strata, described in the last paragraph, emerge and occupy the surface of the upper portion of its course.

Little or no geological mapping has been carried out between Coor-de-Wandy on the Upper Wooramel and Mount Narryer on the Upper Murchison, but between the latter hill and Tilly Gully (b), the older crystalline rocks give place to the almost horizontal sedimentary beds, which make such a prominent feature in the Woodrarrung Range (c), and which, there are very strong geological reasons for believing, represent the southward extension of the carboniferous rocks of the Wooramel.

In the valley of the Murchison River, somewhere below Bompas Hill, is a fairly large development of sedimentary beds. In the vicinity of the 14-mile crossing, some distance above the Geraldine Mine, and 80ft. by aneroid above it, is an exposure of what appears to be an older series of strata than that comprising the Woodrarrung Range. The lowest bed in the section is conglomerate and breccia, composed of angular fragments of quasi-vitreous quartzite, dipping to the east; the base of the conglomerate is not visible. A peculiar feature of some of the pebbles is that they are covered with slicken-sides, which, however, have no prevailing direction. A few yards lower down the river is a bed of quasi-vitreous sandstone overlaid by beds of cross-bedded sandstone and fine conglomer-

(a) Annual Progress Report of the Geological Survey for the year 1902. Perth: By Authority, 1903, pp. 23-24; also Annual Progress Report of the Geological Survey for the year 1903. Perth: By Authority, 1904, p. 34.

(b) Lands Department Lithograph, 8m.

(c) Lands Department Lithograph 6m.

ate, trending north and south, and dipping east at an angle of 20 degrees. One of the sandstone beds has evidently been much faulted, for one of the beds is slickensided to such a degree as to produce surfaces as smooth and polished as plate glass.

Lower down the Murchison the sedimentary beds referred to in the last paragraph give place to the older crystalline rocks (gneiss, etc., with greenstone dykes), which occupy the country to a point on the river in the vicinity of the peg W. 1., on the boundary of Location 66/1135 (a).

Near this point, which is about twenty miles east of the sea coast, the Murchison River enters a narrow gorge, flanked by vertical walls of sandstone and grit. The junction between these sandstones and the older gneissic rocks, as can be seen by a section on the north bank of the river, is a fault dipping to the west. This sedimentary formation occupies the whole of the Murchison Valley as far as its mouth in Gantheaume Bay.

A traverse from Carnarvon to Northampton, *via* Gladstone, Hamelin Pool, and the Murchison River, near Mount Curious, in 1901 showed the staple formation to consist of sandstones, grits, etc., together with their decomposition products, indicating the continuity of the same geological formations seen outcropping on the high ground along the upper portions of the valleys of the Gascoyne, the Wooramel, and the Murchison Rivers.

No observations as to the actual discharge of the Wooramel and the Murchison Rivers would appear to have been made, so that no estimate of the amount of water absorbed by the sedimentary beds can be arrived at. From the available records, it seems that the rainfall of the district is fair, and that, after due allowance has been made for evaporation and run-off, a good deal of the rainfall must disappear underground, and be capable of being reached by wells or bore holes.

Having due regard to all the prevailing geological conditions of the country to which previous reference has been made, it may be said that, on the whole, the area occupied by the carboniferous and newer strata is favourable as regards the possibility of the occurrence of artesian water, whilst so far as can be judged by the present evidence, the chances of obtaining overflowing supplies is greatest on the lower-lying ground near the coast.

To the eastward of the boundary between the carboniferous and newer strata, no hope of obtaining a supply of artesian water exists.

A Geological Sketch Map, Plate I., accompanies this report.

A. GIBB MAITLAND.

**2.—On the country between the Ashburton and Minilya Rivers with a view to determining the northwards extension of the Gascoyne Artesian area.**

*(With a Map.)*

In the immediate vicinity of Onslow, the country is of an estuarine character, consisting of salt marshes and mangrove swamps with blown sand ridges containing large quantities of oyster and other recent shells.

For its water supply the town is dependent upon a number of shallow wells sunk in the sand, the water in which varies very considerably in quality, whilst the supply is limited, being entirely dependent upon the local rainfall.

Beneath the sand hills and swamps a heavy blue clay is met with, in the upper portion of which, if water is struck, it is of an extremely bad quality, whilst all attempts to obtain a supply by sinking through it have so far failed. Some years ago a bore was put down by the Government to a depth of 1,729ft., in which the first supply of water was struck at 1,015ft., which trickled over the surface at the rate of 20 to 30 gallons per diem. At a depth of 1,717ft. a further supply was cut which yielded 120 gallons per diem, the hydrostatic pressure being 10.82lbs. per square inch, and hydrostatic head 25ft. above the surface, the water being salt. The bore passed through shale for the greatest proportion of the depth and was discontinued in black shale, locally known as "black Jack."

Following up the Ashburton River in a southerly direction, large alluvial plains stretch east and west as far as the eye can reach, water being either obtained from the pools in the river bed or from wells sunk in the various groups of blown sand hills which here and there break the monotony of the flats.

This class of country extends for a distance of about 50 miles, where it is suddenly terminated by an outcrop of crystalline rocks, which from this point southward present a fairly bold escarpment to the westward.

Between the Ashburton and Yannarie River are large plains of a more or less flooded character, and it is on to these that the last-mentioned river discharges its waters, at a point upon the telegraph line about 65 miles from Onslow, whilst the plains in flood time drain into the salt flats and marshes lying upon the eastern side of Exmouth Gulf.

This plain country extends up the Yannarie as far as Jane Well (C. 29), from which point the country rises rapidly, the

surface being covered by a red sand, with occasional outcrops of limestone.

At Nganyon Pool (C. 26) the crystalline rocks with quartz reefs make their appearance, overlaid by limestone conglomerate, the junction of the two formations following a line slightly to the east of north.

From Wogoola Station (Cameron and Clark's), upon the Yannarie at its junction with Emu Creek, a road runs south-westward to the Winning Telegraph Station, along which the crystalline rocks outcrop for about six miles to be suddenly replaced by shales. At a point seven miles to the westward of the station a well has been sunk in them to a depth of 80 feet, at which depth a good water supply was struck. These shales are highly altered (locally called kaolin); this change from the normal dark blue is in all probability due to the leaching subsequent to the oxidation of the pyrites, which often occurs associated with them in considerable quantities. At a point 10 miles west of the station another well has been sunk in the shales to a depth of 162 feet, but so far no supply of water has been struck. In this well some green fossiliferous shales were passed through, but these have now all weathered away and only portions of a cast of an ammonite were obtained from Mr. Cameron.

For the next 10 miles a series of clay pans and sandy flats are crossed, after which low shale hills strewn in patches with much quartz and ironstone rubble are passed over, until the telegraph line is reached.

To the northward of the Telegraph Station at Winning and to the westward of the line are a series of altered shale hills, which present a cliff-like face to the eastward, the beds of which have a distinct, although slight dip to the north-eastward.

Between Winning and Towera Station on the Yannarie (Mr. Twitchin's), travelling due east, are a series of low shale hills, of which Mt. Forrest is the highest, then sandy flats are crossed to within a distance of 10 miles of the river, where a shaft has been sunk by the Minilya Roads Board to a depth of 62 feet, in dark shale, without striking water, whilst immediately to the eastward of this point the crystalline series again appear and continue for the remainder of the distance to the station.

From the dry well just mentioned the boundary of the granitic rocks can be traced in a south-easterly direction, sweeping past the Round Hill (which is sandstone) upon the eastern side; thence on south of A. 43 Cairn, crossing the Lyndon River just below marked tree A. 31; from there striking back to the north-east of Sugar Loaf Hill, crossing the flooded flats of the river, which it follows close upon the eastern side to A. 36, where it again crosses, following the White Quartz Hill upon the western side, from which

point it strikes south-easterly on to the Minilya to a little east of Williambury Station, up to which point it has been mapped in by Mr. A. Gibb Maitland, the Government Geologist.

Traversing the river westward from A. 31, limestone conglomerates are seen resting directly upon the crystalline series in the bed of the river, to be overlaid lower down by shales. Between Windalia Pool, A. 29, and Chugareyardoo, A. 49, which is upon a branch creek to the southward, there is an outcrop of heavy schistose boulders associated with crystalline limestone; these may probably indicate shallow ground, since lines of these boulders with parallel lines of foliation are often seen outcropping, whereas if they had been a portion of the glacial series described by the Government Geologist they would have been more disturbed and ice scratched. This is the only locality in the whole area where there appears to be anything like shallow ground within the basin.

About one mile north-east of Cordalia Well, near A. 51, a fossiliferous limestone ridge rises from the plain which strikes in a north-westerly and south-easterly direction, with a well-defined dip to the south-westward. The fossils in these beds are similar to those met with upon the Irwin River, and therefore it may be assumed that these rocks belong to the Lower Carboniferous series.

To the south-westward of this ridge is a well defined range of hills, the basal beds of which are shale, whilst the capping is sandstone or quartzite; these latter beds vary from 20 to 70 feet in thickness.

This range attains its greatest elevation at the south end in Moogooloo Peak, which forms a conspicuous landmark, whilst owing to the vertical cliff-like faces presented by the heavy quartzite capping it is most difficult to climb.

This range appears to be the northern extension of the Kennedy Range, which is also similarly capped.

The beds of this range near A. 51 have a much steeper dip than at any other point noted in the district, therefore, it is either only local, or the dip of this series flattens greatly to the northward, which is quite possible, and would account for the plains without rock outcrops.

Between Cordalia Well and Winning the country is mostly low and rolling, the ranges dying away to the northward of the river, the presence of the various formations being only determined by the nature of the soil.

To the westward of Winning, after the shale hills are crossed, the surface of the country consists of a series of calcareous flat, which give place to low shale hills near the Cordalia Creek.

About ten miles west of that creek, at A. 8, there is a bold limestone range, the rocks of which dip at a low angle to the westward, whilst between it and the coast are a series of flats and sand ridges.

South from Winning along the telegraph line to the Lyndon River the country is undulating, the soil being mostly sandy and calcareous.

The beds of this district fulfil all the conditions necessary to an artesian area, consisting as they do of a series of pervious sandstones and limestones interbedded and overlaid by impervious shales of considerable thickness, the whole having a uniform dip to the westward or towards the coast. At the junction of the artesian series with the granite, the surface elevation varies from 450 to 500 feet above the sea level, the coast being about 75 miles distant; but since about 15 miles of coastal country has practically no elevation, this fall may be condensed into 60 miles, which represents from 7 to 8 feet per mile; therefore as the water level at or near the junction varies from 50 to 100 feet (according to the elevation of the surface), it will follow that a sufficient hydrostatic head cannot be obtained to cause water to rise above the surface until a distance of from 12 to 15 miles west from the outcrop of the crystalline series is reached, although in the intervening distance no doubt sub-artesian water (water rising in bore but not overflowing) will be obtained.

In support of the theory that this is an artesian area, we find in the Lyndon Valley and to the southward the unbroken continuation of the rock series, forming hill ridges, which constitute the proved area of the Gascoyne.

In conclusion, it may be stated that a very fine stretch of pastoral country was passed over, which at the present time is practically valueless, because all attempts to obtain a water supply by the means of shallow wells has so far proved futile.

HARRY P. WOODWARD,  
Assistant Government Geologist.

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### 3.—The Phosphatic Deposits near Dandaraga.

(With a Map and 8 figures.)

*Preliminary Note.*—In the month of September, 1906, a sample of a greenish ferruginous sandstone, which, on examination, was found to contain 14.96 per cent. of phosphoric acid, was received at the offices of the Geological Survey. In view of the great value to the State of the occurrence of a suitable mineral phosphate, it was considered desirable to have a geological examination of the deposit made in the field, and also to carry out certain investigations in the laboratory in connection therewith.

Mr. Campbell, Assistant Geologist, was accordingly instructed to visit the district to inquire, *inter alia*, into the extent of the deposit, its mode of occurrence, its mineralogical constituents, etc., and the utilisation of the deposit. This officer devoted a week to the investigations in the field, and made a collection of the deposits in illustration of his report. These samples were placed in the hands of Mr. Simpson for investigation in the Survey Laboratory, and a typical series are now in the Geological Survey Museum.

The report of Mr. Campbell is accompanied by a plan (Plate III.) showing the extent of the phosphatic deposit, so far as is at present known, together with a series of four photographs and four geological sections. Mr. Simpson's report contains several analyses of the different classes of the deposit.

It appears the deposit occurs in a series of beds, which have been followed across country for a distance of about 22 miles, and the phosphatic rock exposed in several places. The deposit appears to have been originally found on the Midland Railway Company's concession, though the field observations prove it to extend into Crown lands. So far as observations have as yet been carried, there appear to be three distinct classes of material amid the phosphatic deposits (a.) weathered rocks containing from 0.54 to 2.10 per cent. of phosphoric acid; (b.) ferruginous sandstones, containing phosphates mainly of iron with from 7.25 to 15.13 per cent. of phosphoric acid, the iron phosphates occurring as *dufenite* and *vivianite*; and (c.) fossil bone and *coprolite* rock, containing from 15.32 to 39.34 per cent. of phosphoric acid.

The bone bed has been proved to be about three feet thick, whilst the underlying ferruginous sandstone, which has been more or less phosphatised by the interaction of ironstone and phosphoric acid derived from the bone beds, is at least 7ft. in thickness. The bone bed is of course the most important of the deposits, and it is possible that prospecting may result in portions of the deposit

being found to be much richer in phosphoric acid than any of the outcrops yet tested.

The matter of the geological age of the deposit is one of inference only, but I am inclined to regard it as being the northern extension of the Gingin tertiary strata.

These discoveries are of importance, and should act as a stimulant to the search for similar phosphatic deposits in that portion of the Great Coastal Plain, which extends from Perth to Geraldton, for they may easily prove to be more extensive than at present known. So far as can be judged from what is at present to be seen, there seems to be the material for a remunerative industry if properly and judiciously followed up.

A. GIBB MAITLAND,  
Government Geologist.

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The locality where phosphatic deposits have been found on the Midland Railway Company's concession is on a north and south line of country passing four miles west of Dandaraga, which latter place is 22 miles to the westward of Moora, and is connected with it by a well-made road. The intervening country is largely a sandplain until about 14 miles out from Moora, when a series of low limestone hills are met with showing a considerable fertility of soil. The hills rise rather higher on the west side of Dandaraga and form the dominant range in the district. These hills are mostly well wooded, and are composed of ferruginous sandstone, they form a line of steep escarpments and bluffs towards the west, from the foot of which extend many miles of sandplains, mostly destitute of timber. These ferruginous beds are nearly horizontal, with a slight inclination to the east in places, and contain indurated bands on the top of one of which the phosphatic bed or beds occur, and are seen on a subsidiary line of escarpments about a mile back from the main line of which Cowalla Bluff forms a part, and also at the base of some white limestone or chalk-like hills thirteen miles to the north. These localities extend over a distance of about 22 miles.

The place where the phosphate samples were first obtained is about six chains south-easterly from the south-east corner of Location 957 (James Burnett's); here the upper portion of the outcropping ledges of rock on the track show about one foot in thickness, having a mottled green colour, which attracted the attention of Mr. James Gardiner when driving along the track, and he collected some samples and forwarded them to this Department

and to the Government Analyst, when they were found to be phosphatic, containing from 10 to 15 per cent. of phosphoric acid. The source of this acid is a bone bed that overlies it and which being softer has decomposed at the surface of the ground, leaving only a few blocks scattered about. It contains fragments of bone, teeth or tusks of saurians and whitish nodules (so-called coprolites), which latter have been probably formed by the aggregation of phosphate of lime. The report of the Mineralogist and Assayer shows that the green colour of the rock is due to the mineral dufrenite, the phosphoric acid having combined with peroxide of iron to form that mineral. He also reports the presence of both vivianite (hydrated phosphate of iron) and wavellite (hydrous phosphate of alumina). The beds have thus both rock and organic phosphates.

Since my visit I have been shown specimens obtained from holes sunk adjacent to this outcrop; these show a better grade of phosphate, and that the bone bed is at least three feet thick, and that the green alteration of the bands of sandstone extends down to ten feet depth in the deepest of the holes, which have bottomed on to very hard sandstone.

The same formation is to be seen at the ledge of rock,  $\frac{3}{4}$  mile to the north near Mr. Burnett's house, but the bone bed is not so much in evidence there. (Figures 1 and 2, and Mineral Specimens 6962, 6977-80.)

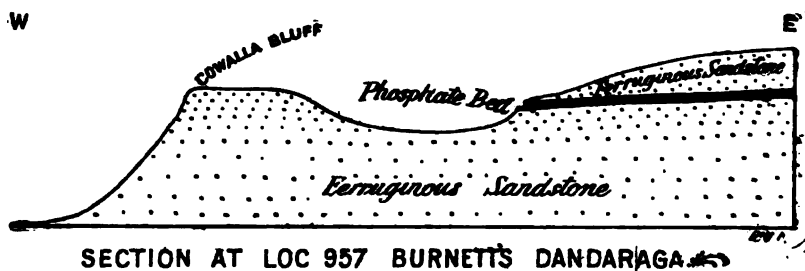
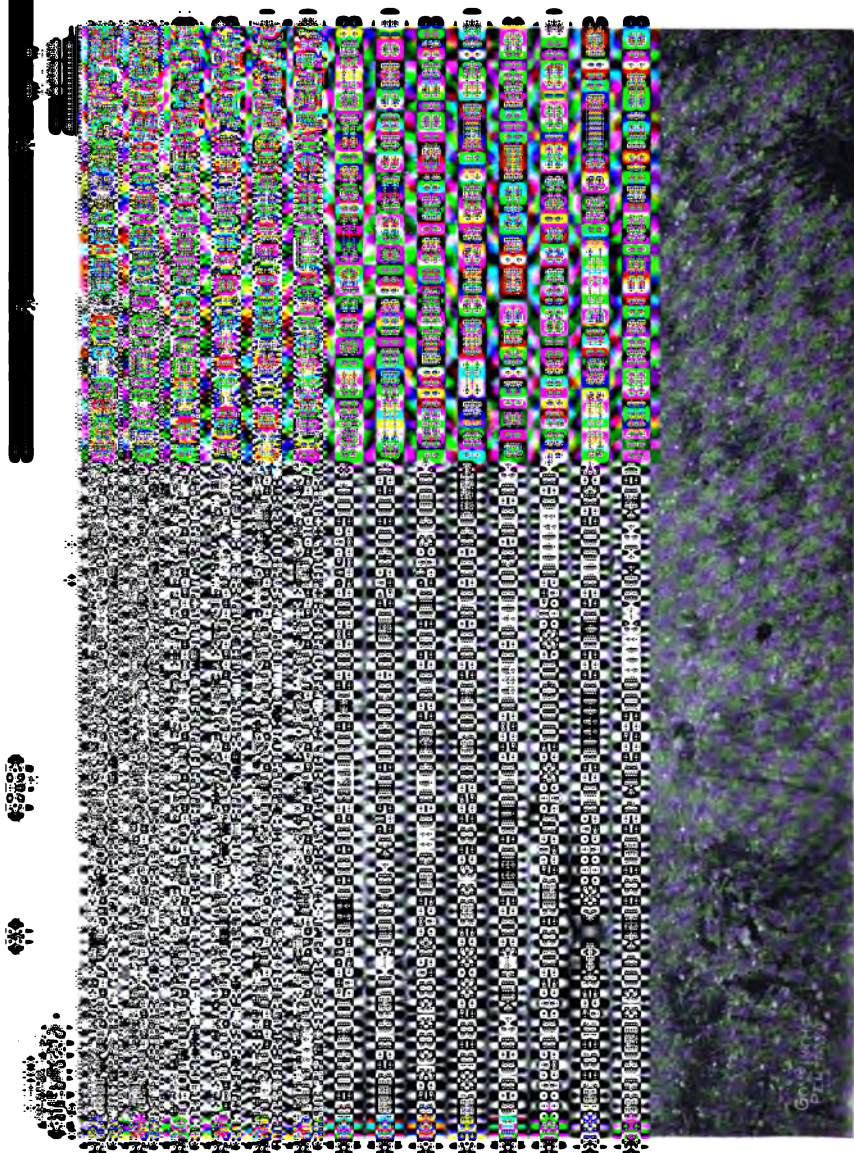


FIG. 1.

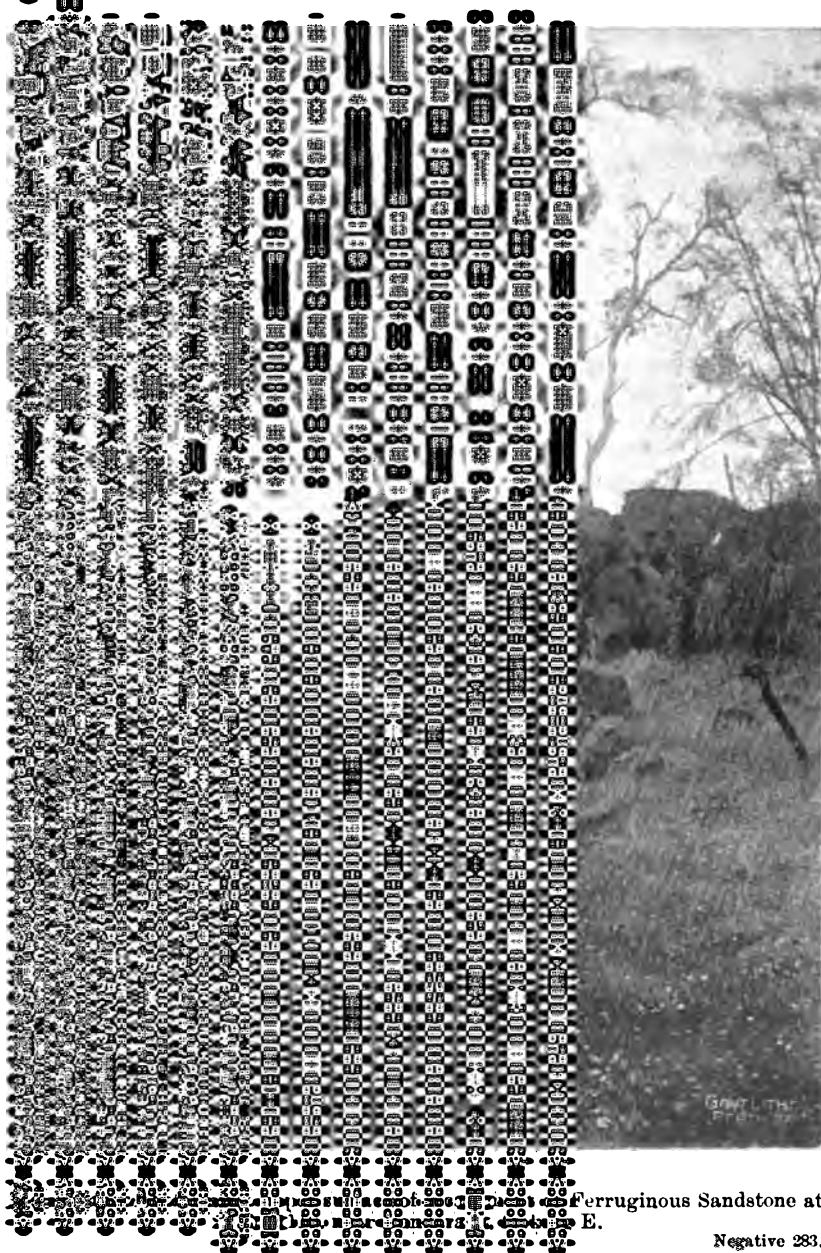
Similar beds occur about  $4\frac{1}{2}$  miles in a direct line southerly at the western side of Location 1110 (Mr. Bower's); there is here a low escarpment to the west. The phosphate bed probably underlies the surface across from there to an eastern escarpment of a small gully, where there is a small cave known as the "Hole in the Wall," a distance of about 30 chains. The upper portion of this ledge is green-coloured, and is phosphatic, and a tank which has been excavated in it shows that the bone bed also exists here to a depth of six feet at least. (Figures 3, 4, and 5, and Mineral Specimen 6984.)



Phosphate beds, 6 chains S.E. from S.E. corner of Loc. 957, near Dandarsga, looking E.



FIG. 4.



Ferruginous Sandstone at  
E.

Negative 283.

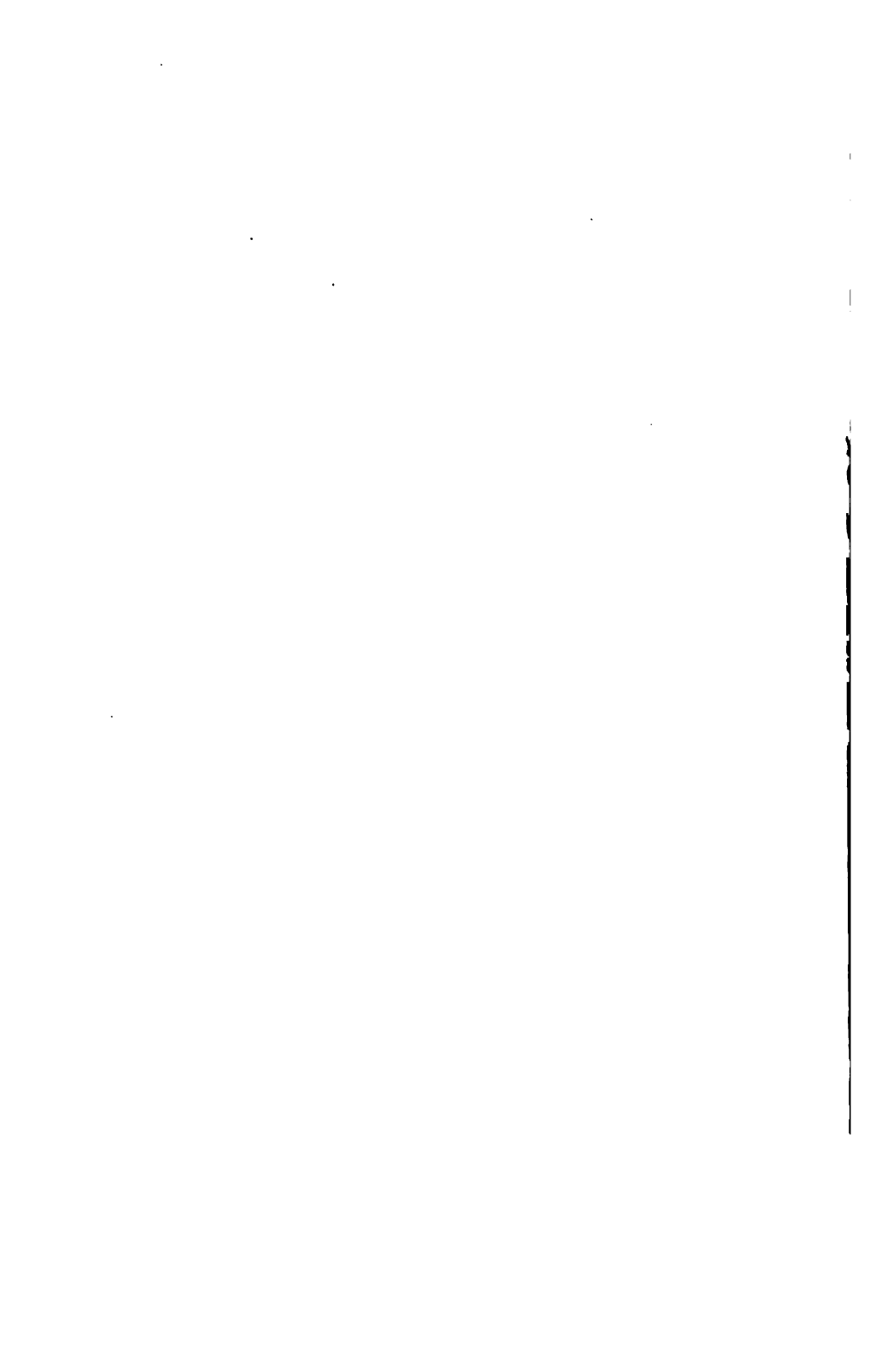
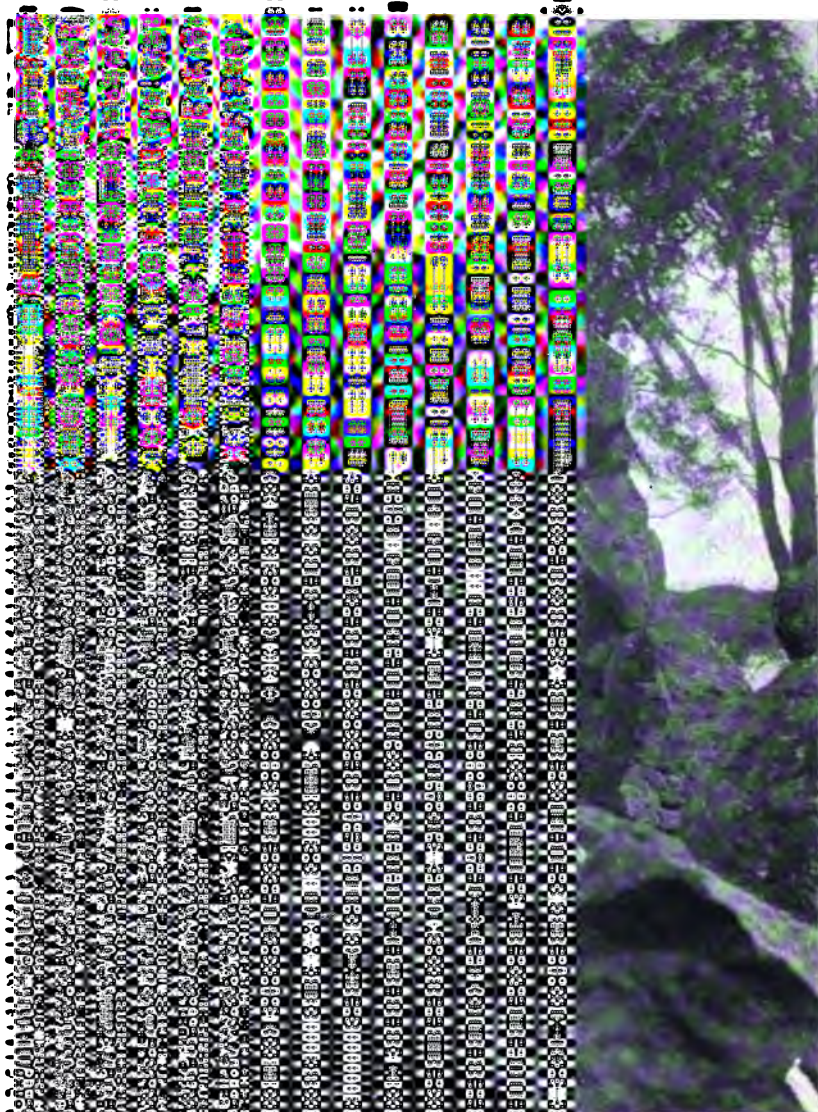




FIG. 5.

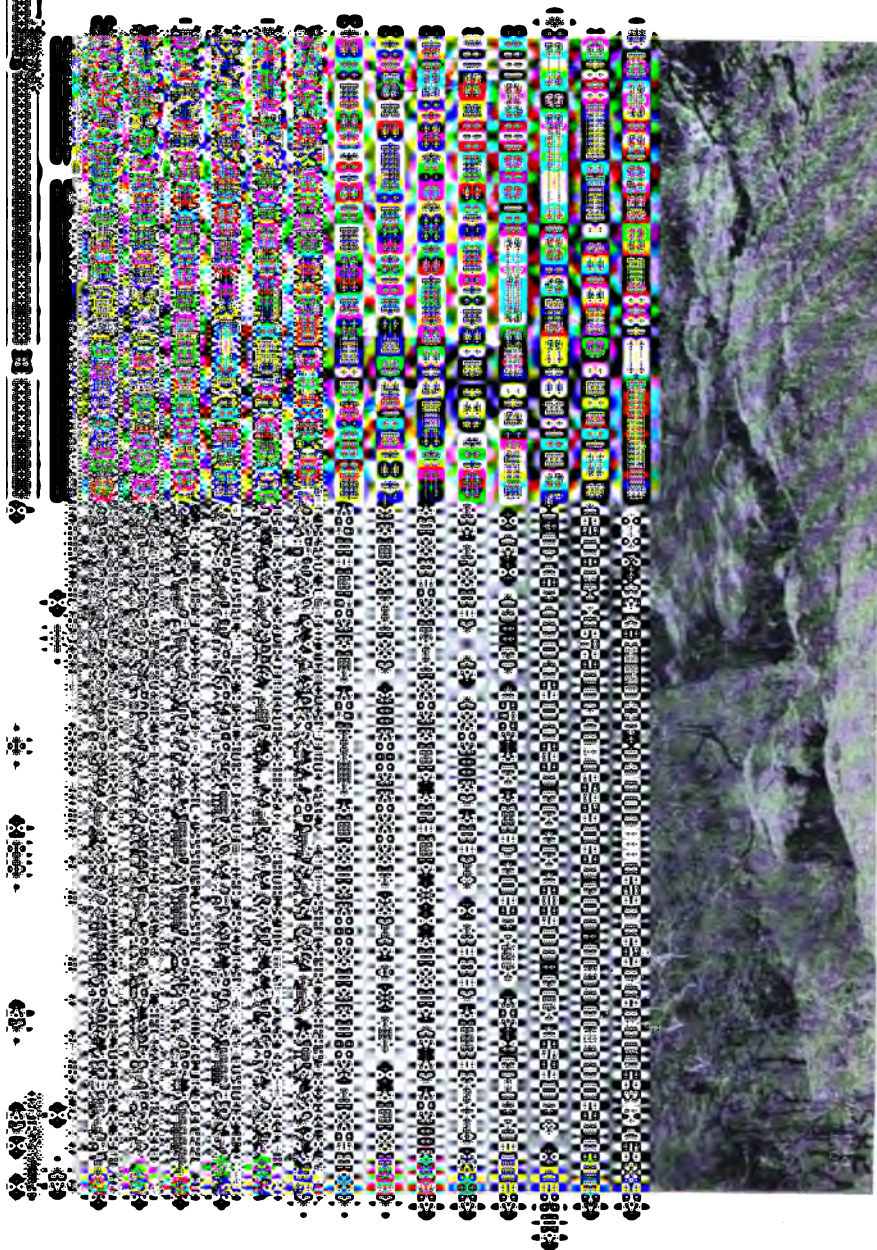


0, close to Fig. 4.

Negative 284.







Phosphate bed above caves, 2½ miles N.E. from Yandan Hill, near Yatheroo, looking E.



Four miles south again from here there is a conspicuous cliff facing the north, known as "The Caves." These caves have been formed by the action of the water penetrating cracks in the hard

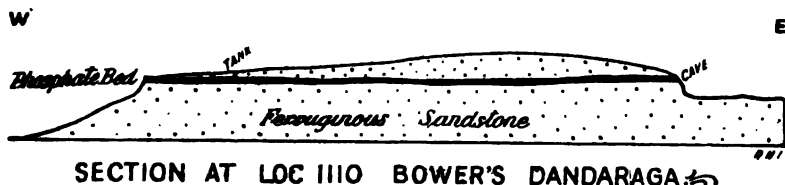


FIG. 3.

ledge, and washing away the underlying softer rock. Heavy rain had fallen the day before my visit, and the fresh marks of running water were very plain. Some of the caves are over 50ft. long, and, in some places, 8ft. high. The upper surface of the ledge has the green-coloured rock, and above it are fragments of the bone bed and nodules. The hill top is wooded to the face of the cliff, along the foot of the cliff also there is a strip of large timber growth, but south-westerly from here the timber becomes scarcer, and at 2½ miles is the bare Yondan Hill, which I visited, but did not go beyond as the country looked unpromising, and any further outcrop of the phosphatic bed would probably have to be sought for nearer Yatheroo. (Mineral specimen 6981-2, and Figure 6.)

Northwards of Cowalla the escarpments disappear, and the line of hills is broken up, the timber growth lessens, and I did not hear of any ledges of this ferruginous green rock about there.

In Location 400, Mordo, a tank has been excavated in either a fine-grained ferruginous sandstone or a decomposed greenstone, the upper portion of which has a greenish colour and contains from 2.10 per cent. of phosphoric acid ; but I did not see any sign of the bone bed, as a bed of laterite of about a foot thickness conceals the underlying sandstone. The country around is flattish with only scanty timber. (See Mineral Specimen 6985.)

Two miles farther north is Pickera Pickera, where a similar rock outcrops near the track (Mineral Specimen 6983) with only .54 per cent. of phosphoric acid. It is quite possible that the bone bed may never have existed here, and that the phosphoric acid at both these two locations may have been the result of the denudation of the bone bed in the neighbourhood.

Six miles farther north at Wathingarra (Emu Hill) there is a white limestone or chalky hill, the western foot of which is intercalated with sandy seams, and with them is a bone bed outcropping near the track. The greater part of the hill is composed of a very pure limestone, a sample from the top of the hill, when examined,

showed a slight trace of phosphoric acid ; some silicified pieces of wood were found on the hill, probably caused by the same conditions that have solidified a white sand and gravel at Location 867 (Whitfield's), about three miles south-easterly from here, into a quartzite bed from 4ft. to 8ft. thick, which underlies about 6ft. to 10ft. of laterite. Both here and at Emu Hill there is a total absence of the ferruginous zones that are such a marked character of the other localities mentioned. (Figures 7 and 8, and Mineral Specimens 6888-90.)

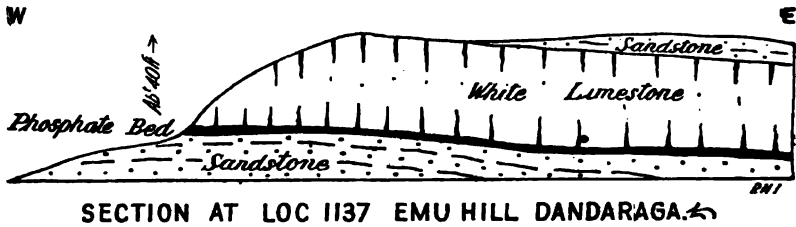


FIG. 7.



FIG. 8.

In each instance the bone bed evidently forms part of the sequence of the beds in the district, all being of one geological series, and it may be found that the bone bed is repeated at a higher or lower horizon on the series, and that the Emu Hill bed is not the same as that at Location 957.

In the map accompanying the report of the then Government Geologist, Mr. H. Y. L. Brown, the Gingin, Yatheroo, and Dandaraga patches of limestone are shown, and both that and the "ferruginous claystone, limestone, sandstone, and grit" are classed as of mesozoic age (Oolitic period of the Jurassic series), and on pages 11 and 13 of his report, he says that the average thickness of these beds where best developed is 400ft., and average elevation about 600ft. above sea level, the surface accumulations of sand preventing its being ascertained whether the limestone over or underlies the ferruginous rock of the district.

The fragmentary and greatly decomposed state of the specimens that I have obtained from the outcrops of the bone beds

prevents much assistance being derived from them towards the identification of their geological horizon at present. There is, however, a great resemblance of the characteristics of the bone bed series with the ferruginous sandstones of the Greenough River district which contain Jurassic fossils, and Mr. H. Y. L. Brown has mapped them as being of the same series.

In both localities the current bedding of the sandstones and the ferruginous bands of floors denote that they were formed in either estuaries or lagoons which were liable to be dried up at times causing probably the destruction of most of the marine creatures inhabiting them.

I did not hear of the occurrence of phosphatic material at any other tanks or wells along the route of travel between the above-mentioned localities, and my inquiries were necessarily more particularly directed towards the existence of the green-coloured rock, which alone appears to have been noticed by residents of the district, who, however, thought that the colour was due to the presence of copper. At Cowalla, the horizon of the phosphate bed appears to be below the summit of the bluff, but it being very steep and disadvantageous as a working ground, I did not ascertain whether it existed there. At Emu Hill there are no ferruginous ledges nor green-coloured rocks, but the bone bed probably extends along the outcrop of that horizon of the limestone hills. Around here the timber is scanty, and white gum has replaced the red gum, the neighbourhood of Cowalla being, I understand, the northernmost limit of that tree, and Yatheroo that of the jarrah. The strong growth of vegetation in portions of the district is due probably to the existence of both limestone and phosphate beds, independently or in conjunction.

It will be seen from the above particulars that there appears to be here the material for a remunerative industry, for the phosphatic deposits evidently extend over a considerable area.

The bone beds somewhat resemble the Cambridgeshire coprolite beds in England, of which I have had experience, and the procedure for the exploration and working of the deposit will be much the same, viz., by trial holes, and then excavating the open trenches, first stripping down to the bed and working up hill until the depth reached makes it too costly for the amount of phosphate obtained. The material from the bone bed would have to be concentrated by screening, washing, or hand-picking, but a difficulty presents itself through the softness of the phosphatic nodules and bones, which will require great care to prevent that material from being lost in the sandy matrix.

The Cambridgeshire coprolites and the South Carolina nodules are readily separated by either washing or screening on account of their hardness. After concentration, the phosphate lumps would

then have to be ground in roller pans, when it could be sold as raw phosphate, or be manufactured into superphosphate by mixing with sulphuric acid, which produces a hydrous and water-soluble phosphate, and a sulphate of lime or gypsum.

The raw phosphate does not decompose readily, and may even take years to benefit the ground ; in the superphosphate form the phosphoric acid is more readily assimilable, and is therefore more in demand when not too costly.

The green-coloured rock which underlies, or is intercalated in the bone bed, would have to undergo a different treatment, which is referred to by Mr. Simpson in his report attached, and possibly special treatment to meet the special material would have to be devised.

For the convenience of prospectors, it may be mentioned that for the field examination of samples dissolve in warm nitric acid, then strain off the residue to a clean solution ; when cold put a few drops into a solution of ammonium molybdate, when, after a few minutes, a bright yellow precipitate should appear. If the material is insoluble in nitric acid, it may be fused in a sodium carbonate bead, and then dissolved in this acid (see p. 102 Brush and Penfold's Determinative Mineralogy). A great deal of useful general information is given on the subject of phosphates in a pamphlet by Dr. Charles Chewings, issued by the Government Printer, Adelaide, 1903.

W. D. CAMPBELL,  
Assistant Geologist.

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## Appendix I.

LIST OF SPECIMENS IN THE GEOLOGICAL SURVEY MUSEUM  
FROM DANDARAGA.

| Registered No. | Rock.                                      | Obtained from. | Locality.                                                             |
|----------------|--------------------------------------------|----------------|-----------------------------------------------------------------------|
| 6977           | Phosphate of Iron Rock ...                 | Surface        | Near S.E. corner of Loc. 957, Dandaraga                               |
| 6978           | Do. do. ...                                | do.            | Near S.E. corner of Loc. 957, Moora district                          |
| 6979           | Bone Bed ...                               | do.            | do.                                                                   |
| 6980           | Do. ...                                    | do.            | do.                                                                   |
| 6981           | Laterite ...                               | do.            | The Caves                                                             |
| 6982           | Laterite with Phosphate of Iron            | do.            | do.                                                                   |
| 6983           | Laterite with Phosphate of Iron, Weathered | do.            | Loc. 132, Pickera Pickera, near Dandaraga                             |
| 6984           | Phosphate of Iron Rock...                  | do.            | Loc. 1110, near tank, Dandaraga                                       |
| 6985           | Do. do. ...                                | do.            | Mardo tank, Loc. 400, Dandaraga                                       |
| 6986           | Quartzite capping of hill                  | do.            | Loc. 867, Whitfield's, Dandaraga                                      |
| 6987           | do.                                        | do.            | do.                                                                   |
| 6988           | Silicified wood ...                        | do.            | Loc. 1187, Wathingarra (Emu Hill), Dandaraga                          |
| 6989           | Bone Bed ...                               | do.            | do.                                                                   |
| 6990           | Limestone from top of hill                 | do.            | do.                                                                   |
| 6992           | Chalcedony ...                             | do.            | 1 mile east of Moora, Dandaraga                                       |
| 6993           | Ferruginous Quartzite ...                  | do.            | do.                                                                   |
| 7017           | Bone Bed ...                               | 3ft. deep      | Near S.E. corner of Loc. 957, hole 5 feet deep, 8 chains east of road |

## Appendix II.

## COMPOSITION OF THE PHOSPHATIC ROCKS.

I have examined the series of phosphatic rocks collected by Mr. Campbell at Dandaraga as far as at present possible with the limited staff at my disposal.

Roughly three main classes of material were included in the samples.

A. Weathered rocks doubtfully phosphatic.—The results obtained on these were:—

L.2613. Average of M6983.—Weathered ferruginous rock with a little green staining;  $P_2O_5$ , 0.54%.

L.2616. Average of M6985.—Weathered greenstone (?).  $P_2O_5$ , 2.10%.



Neither of these samples are of any value whatever.

B. Ironstones carrying phosphates, mainly of iron.—The analyses of these are:—

| L.   | Total $P_2O_5$ . | Ferric Oxide. | Silica and Insoluble Silicates. | Water and Organic Matter. | Carbonic Acid. |
|------|------------------|---------------|---------------------------------|---------------------------|----------------|
| 2600 | 7.25             | 32.14         | 47.54                           | 7.35                      | Trace          |
| 2601 | 9.63             | ...           | ...                             | ...                       | Strong trace   |
| 2614 | 15.13            | ...           | ...                             | ...                       | Strong trace   |
| 2615 | 7.41             | ...           | ...                             | ...                       | Trace          |

2600. Average of M6977.—Ferruginous sandstone impregnated with Dufrenite (hydrated phosphate of iron). Sample contains only 0.08 per cent. of lime. Of the phosphoric oxide present 6.63 per cent. is insoluble and 0.62 per cent. soluble when digested for a week with 1 per cent. citric acid solution. Only one-tenth therefore of the total phosphoric oxide present is available for plant food in its present state.

2601. Ink-coloured portion of M6978.—This is similar to the previous sample, but appears to contain as well as Dufrenite a second iron phosphate, Vivianite.

2614. Typical specimen of M6982.—Light brown siliceous ironstone with paler nodules.

2615. Average of M6981.—Heavy dark brown siliceous ironstone, with light brown concretions.

The first of these four samples is similar to the first sample brought to Perth from this locality. It showed 14.96 per cent. of phosphoric acid, and my report upon it is applicable to the present (B) set of samples.

"For a fertiliser the sample as submitted is low in phosphorus, and the amount of that constituent available for plant food in its present state appears to be very minute, dilute citric acid having an extremely slow effect upon it. Before any practical use could be made of this material means must be resorted to to render the phosphoric oxide soluble. The usual method of treating rock phosphate, viz., converting into superphosphate by treatment with sulphuric acid would be inapplicable in this case where such a large proportion of iron oxide is present. The most feasible method of utilisation seems to be the manufacture of 'Precipitated Phosphate' by solution of the phosphorus and precipitation with lime or calcium sulphide. By this means a very rich fertiliser could be obtained. If dufrenite be the only phosphatic mineral in this deposit it is evident that the highest proportion of phosphoric oxide that could be present in any part of it would be that present in pure dufrenite, viz.:—28 to 32 per cent., whilst the average would be well below that owing to admixture of sand, clay, and limonite. It seems probable, however, that the original source of the phosphorus was coprolite or bone phosphate, which by interaction with iron compounds has given rise to dufrenite. Either of the former phosphates would be of more value than the last named, being both richer in phosphoric oxide and readily converted into superphosphate."

In years to come, when the steel industry is an established fact in Australia, there will probably be a demand for the more ferruginous samples for the simultaneous manufacture of basic steel and Thomas' phosphate.

C. Fossil Bone and Coprolite Rock. The prediction that the iron phosphate was a secondary mineral derived from the interaction of ironstone and phosphoric acid derived from bone or coprolite beds has been verified by Mr Campbell.

The following are analyses of typical samples of these beds:—

| L.   | Total P <sub>2</sub> O <sub>5</sub> . | Lime. | Ferric Oxide. | Silica and Insoluble Silicates. | Water and Organic Matter. | Carbonic Acid. |
|------|---------------------------------------|-------|---------------|---------------------------------|---------------------------|----------------|
| 2602 | 18.26                                 | 15.80 | 26.42         | 21.27                           | 7.88                      | Very small     |
| 2603 | 39.34                                 | ...   | ...           | 1.87                            | ...                       | Small          |
| 2604 | 26.26                                 | ...   | 4.17          | 28.06                           | 2.50                      | Small          |
| 2610 | 15.32                                 | ...   | 29.31         | 27.02                           | 9.60                      | Very small     |

**2602.** Average of **M6979**. Yellowish and greenish mottled rock with base of ferruginous sand carrying a little dufrenite, and enclosing numerous fossil bones and lime phosphate nodules (coprolites) of all sizes. Most of the phosphoric acid in this sample is present as lime phosphate, a little, however, is present as iron phosphate (dufrenite) and a little as aluminium phosphate (wavellite). The whole of it is "acid soluble"; 7.06 per cent. of the phosphoric oxide is soluble in 1 per cent. citric acid in one week and is therefore available for plant food, 11.20 per cent. is insoluble in this solution. Such material, if very finely ground, might be used with advantage on the swamp soils of the South-West of this State, but being very slow in action compared with superphosphate would probably not be received with much favour by the farmers. Its value at the rates published by the Agricultural Department would be £2 17s. per ton. A higher grade sample of similar material has been presented to the Department by Mr. Jas. Gardiner.

**2603.** Bone (tusk?) from **M6979**. This is a fair sample of the large pieces of bone present in the previously described sample. It contains 85.88 per cent. of lime phosphate and only a trace of iron.

**2604.** Phosphatic nodule or coprolite from **M6979**. Contains 57.33 per cent. of lime phosphate, and is therefore similar to much of the lower grade coprolite and pebble-phosphate which is converted into superphosphate.

**2610.** Average of **M6980**. Similar to **L2602** already described, but contains no visible iron phosphate and is more porous and friable, having apparently been subjected to considerable leaching action.

Both of the samples of the bone-coprolite beds examined are too low in phosphoric oxide to be worth converting into superphosphate. That richer samples are, however, to be obtained is shown by Mr. Gardiner's specimen. With cheap locally made sulphuric acid even the lower grades might be used for the production of high-grade precipitated phosphate.

If the bones and coprolites can be successfully separated from the enclosing non-phosphatic sand rock by coarse crushing and screening, or otherwise, an excellent high-grade raw material would be obtained, carrying from 60 to 70 per cent. lime phosphate, and therefore well suited for conversion into superphosphate.

The latest published local values for phosphoric acid in fertilisers are as follow:—

|                                                     |     |     |     |     |               |
|-----------------------------------------------------|-----|-----|-----|-----|---------------|
|                                                     |     |     |     |     | s. d.         |
| Water-soluble                                       | ... | ... | ... | ... | 5 2 per unit. |
| Citrate-soluble                                     | ... | ... | ... | ... | 3 10 " "      |
| Acid-soluble                                        | ... | ... | ... | ... | 2 7 " "       |
| P <sub>2</sub> O <sub>5</sub> in bones, offal, etc. | ... | ... | ... | ... | 3 0 " "       |

EDWARD S. SIMPSON,  
Mineralogist and Assayer.

#### 4.—Notes on a Meteorite from the Nuleri District of Western Australia.

(With 6 figures.)

The small meteorite (5025) here described, was presented to the writer by W. R. Feldtmann, Esq., in 1902, with the information that it was obtained from a prospector, who said he picked it up in the uninhabited interior somewhere about 200 miles east of Sir Samuel. According to this it would have been found either close to or within the boundaries of the Nuleri Land District, and it is proposed therefore to call it the Nuleri meteorite.

Its general appearance is shown by Figs. 9 and 10. It is a Siderite of the octahedrite type. Its total weight was 120.2 grammes; extreme length, 60mm.; extreme width, 46mm; extreme thickness, 22mm. It is evidently not an entire boloid but a small fractured portion of a large mass, probably fractured naturally in falling, since the fractured surfaces have a crust very similar to that on the original external surface. About one quarter of the surface exhibits the typical external appearance of a siderite being pitted and covered with a glazed surface, varying in colour from black to dark brown. The remainder of the surface is formed by broad faces of the octahedron covered by a thin coating of black magnetite. The mass is penetrated deeply in places by fractures along octahedral cleavage planes. A number of minute moist globules, brownish yellow in colour, occurred on the cleavage faces when first received. These proved on examination to be iron perchloride ( $\text{Fe}_2\text{Cl}_6$ ), showing that lawrencite (iron protochloride) is a constituent of the mass.

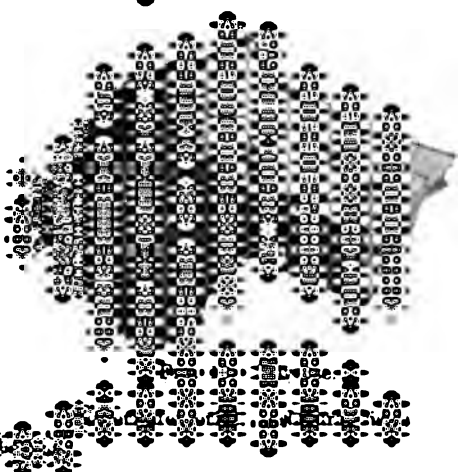
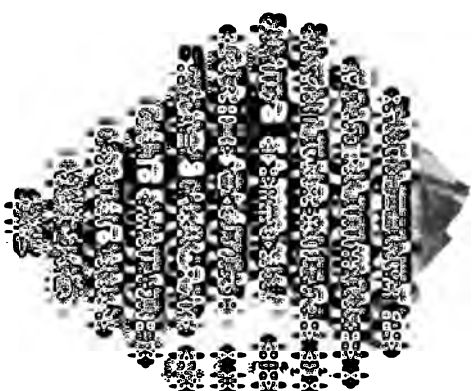
Taking advantage of the deep fractures, portions weighing in all 10.7 grammes, were broken off with a cold chisel for chemical and structural examination, leaving the main mass weighing 109.5 grammes.

*Internal structure.*—A cleavage flake, 30 millimetres long and 3mm. thick, was carefully polished on one side and then etched with nitric acid of normal strength for about two minutes in order to develop the internal structure. This was found to be very interesting, a beautiful damascened structure being brought out. This is well shown in Fig. 11. A similar structure is recorded by Fletcher as occurring in the Youndegin iron, though nothing resembling it appears on the fragment of that iron in the Perth Museum.

The different constituents observed were three, viz.:—

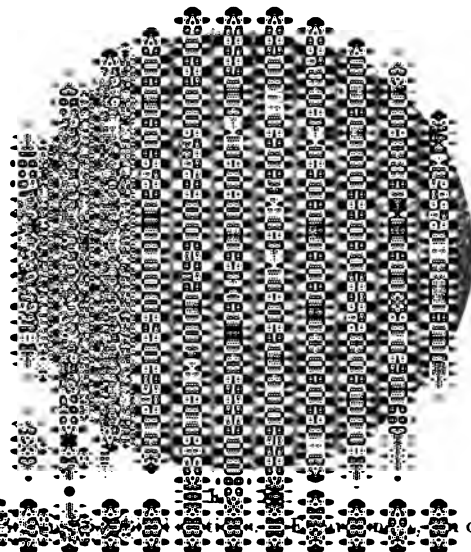
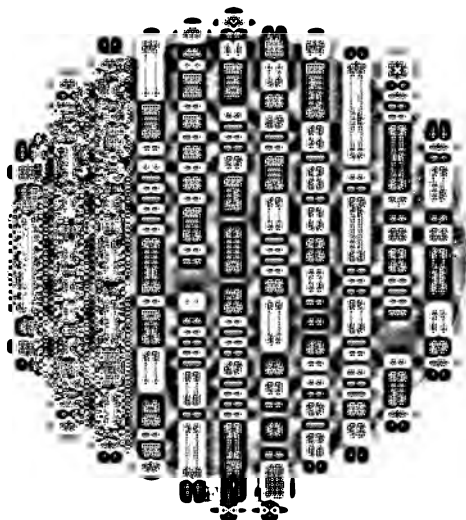
(1.) A dull grey iron-nickel alloy forming the greater part of the surface. This was evidently the constituent most attacked by the acid.

(2.) A much brighter iron-nickel alloy, but little affected by the acid and occurring in numerous long slightly curved lenticular

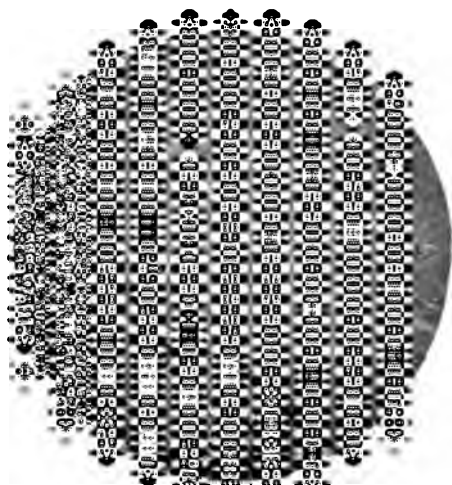
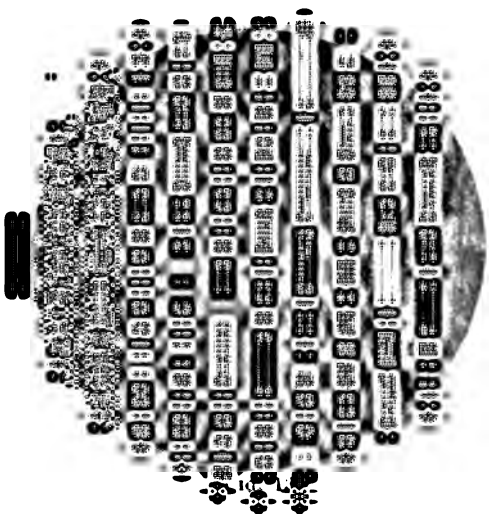








diameters.)



ten diameters.)





wisps, for the most part from one-twentieth to one-fifth of a millimetre in thickness, as seen in Figs. 11 and 12. There are two interlacing sets of these lenticles each roughly parallel to one of the octahedral cleavages, one being much more developed than the other. No lenticles appear to follow the third cleavage. The second, less prominent set, is best seen in Fig. 13, but may also be seen in Fig. 11. On one portion of the surface this mineral is much more largely developed, forming an M shaped area, one leg of which is seen to cross the centre of Fig. 12.

(3.) A brilliant tinwhite mineral occurring in very small amount, and that very irregularly distributed, being confined to two widely separated areas. Its outline at one of these points resembles Arabic writing, as seen in Fig. 14; at the other shown in Fig. 13 there is a singular tabular crystal parallel to a cleavage, about 2mm. long and 0.3mm. wide. In both cases the illumination of the surface when the photographs were taken was such as to suppress the brilliancy of this mineral. It appears therefore to be almost black. This mineral is probably schreibersite (phosphide of iron and nickel).

The only other notable point brought out by etching was the octahedral cleavage in three directions at an angle of 60 degrees with one another, the fourth cleavage being parallel to the surface of the plate.

*Chemical composition.*—A fragment of the meteorite weighing about 5 grammes was carefully cleaned by filing, etc., and finally analysed, with the results given below. For comparison I have attached the analyses of three of the only other five undoubted meteorites yet discovered in this State. No analyses would appear to have been made of the Mooranoppin and Mt. Stirling irons:—

| Name       | Hamersley Range<br>(Roebourne). | Ballinoo<br>(Mt. Erin). | Youndegin. | Nulert. |
|------------|---------------------------------|-------------------------|------------|---------|
| Class.     | Om                              | Off                     | Og         | P       |
| Iron       | 90.91                           | 89.91                   | 92.67      | 93.57   |
| Nickel     | 8.33                            | 8.45                    | 6.46       | 5.79    |
| Cobalt     | .59                             | .74                     | .55        | .41     |
| Magnesium  | Nil                             | Nil                     | .42        | .09     |
| Copper     | Nil                             | Trace                   | Trace      | Trace   |
| Carbon     | Trace                           | Trace                   | .04        | .01     |
| Phosphorus | 1.16                            | .50                     | .24        | .13     |
| Sulphur    | Trace                           | Trace                   | Nil        | Trace   |
| Silicon    | .01                             | Trace                   | Nil        | Nil     |
| Chlorine   | ...                             | ...                     | ...        | Trace   |
| Total      | 100.00                          | 100.00                  | 100.38     | 100.00  |
| Sp. Gr.    | 7.78                            | 7.8                     | 7.86-7.72  | 7.79    |

Assuming that the whole of the phosphorus is present as schreibersite, the mineral composition of the meteorite would be—

|                    |    |    |    |                 |
|--------------------|----|----|----|-----------------|
| Schreibersite      | .. | .. | .. | 0.84 per cent.  |
| Nickel-iron alloys | .. | .. | .. | 99.16 per cent. |
| Lawrencite         | .. | .. | .. | Trace.          |

Owing, however, to the very irregular distribution of the constituents disclosed by polishing and etching, and to the fact that only a small fragment (15 grams.) could be used in making the analysis, the chemical composition given above must be looked upon as only approximate for the whole mass.

EDWARD S. SIMPSON,  
Mineralogist and Assayer.

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## 5.—The Geology of Princess Royal Harbour with reference to the occurrence of oil.

(With a Map.)

The idea of the possibility of the occurrence of oil-bearing rocks in Princess Royal Harbour appears to have been very largely based upon the fact that during the progress of dredging operations therein oil rose to the surface, and pieces of bitumen were brought up by the Government dredge.

This led to the formation of the Princess Royal Harbour Mineral and Oil Company for the purpose of prospecting for both mineral and oil ; and an application to the Department for State aid in the prosecution of the venture.

A personal inspection of about twelve days' duration was made by myself of the harbour and its surroundings, for the purpose of acquiring the necessary data at first hand.

A good deal of geological information on the vicinity of Albany appears in the various official and other reports which have appeared as far back as the year 1879 ; and as these contain some information which has an important bearing upon the question, they are somewhat freely quoted.

The geological structure of Bald Head at the entrance to King George's Sound was described by Vancouver in 1791 :—

The principal part of this country appeared to be Coral, and it would seem that its elevation above the ocean is of modern date, coral being found on the highest hills we ascended, particularly on the summit of Bald Head. In these fields of coral, seashells were in great abundance. (a)

Darwin, however, seems to have been the first to have correctly grasped the geological structure of King George's Sound :—

This settlement is situated at the south-western angle of the Australian continent. The whole country is granitic, with the constituent minerals sometimes obscurely arranged in straight or curved laminae. . . . These plutonic rocks are, in many places, intersected by trappean dykes. In one place I found ten parallel dykes ranging in an east and west line; and not far off, another set of eight dykes, composed of a different variety of trap, at right angles to the former ones. . . . The lower parts of the country are everywhere covered by a bed, following the inequalities of the surface of a honeycombed sandstone, abounding in oxides of iron.

A calcareous deposit on the summit of Bald Head, containing branched bodies, supposed by some authors to have been corals, has been celebrated by the descriptions of many distinguished voyagers. It folds round and conceals irregular hummocks of granite at the height of 600 feet above the level of the sea. It varies much in thick-

(a) *Voyage of Discovery*, Vol. I., pp. 165-6, 1801.

ness; where stratified, the beds are often inclined at high angles, even as much as at 30 degrees, and they dip in all directions. These beds are sometimes crossed by oblique and even-sided laminae. The deposit consists either of a fine white calcareous powder, in which not a trace of structure can be discovered, or of exceedingly minute rounded grains of brown, yellowish, and purplish colours, both varieties being generally, but not always, mixed with small particles of quartz, and being cemented into a more or less perfect stone. . . . Both of the above mentioned varieties of calcareous sandstone frequently alternate with, and blend into, thin layers of a hard substalagmitic rock, which, even when the stone on each side contains particles of quartz, is entirely free from them; hence we must suppose that these layers, as well as certain vein-like masses, have been formed by rain dissolving the calcareous matter and reprecipitating it. . . . Each layer probably marks a fresh surface, when the now firmly cemented particles existed as loose sand. These layers are sometimes brecciated and recemented, as if they had been broken by the slipping of the sand when salt. I did not find a single fragment of a seashell; but bleached shells of the *Helix melo*, an existing land species, abound in all the strata; and I likewise found another *Helix* and the case of an *Oniscus*.

The branches are absolutely undistinguishable in shape from the broken and upright stumps of a thicket; their roots are often uncovered and are seen to diverge on all sides; here and there a branch lies prostrate. The branches generally consist of the sandstone, rather firmer than the surrounding matter, with the central parts filled, either with friable calcareous matter, or with a substalagmitic variety; this central part is also frequently penetrated by linear crevices, sometimes though rarely containing a trace of woody matter. These calcareous branching bodies appear to have been formed by fine calcareous matter being washed into the casts, or cavities, left by the decay of branches and roots of thickets, buried under drifted sand. The whole surface of the hill is now undergoing disintegration, and hence the casts which are compact and hard are left projecting. In calcareous sand at the Cape of Good Hope I found the casts, described by Abel, quite similar to these at Bald Head; but their centres are often filled with black carbonaceous matter, not yet removed. It is not surprising that the woody matter should have been almost entirely removed from the casts on Bald Head, for it is certain that many centuries must have elapsed since the thickets were buried; at present, owing to the form and height of the narrow promontory, no sand is drifted up, and the whole surface, as I have remarked, is wearing away. We must therefore look back to a period when the land stood lower, of which the French naturalists found evidence in upraised shells of recent species, for the drifting on Bald Head of the calcareous and quartzose sand, and the consequent embedment of the vegetable remains. . . . Reflecting on the stratification of the deposit on Bald Head; on the irregularity of alternating layers of substalagmitic rock; on the uniformly-sized and rounded particles, apparently of seashells and corals; on the abundance of land shells throughout the mass, and, finally, on the absolute resemblance of the calcareous casts to the stumps, roots, and branches of that kind of vegetation, which would grow on sand hillocks, I think there can be no reasonable doubt, notwithstanding the different opinion of some authors, that a true view of their origin has been here given (a).

These observations of Darwin's, which have been quoted at length, are of importance in that they conclusively prove that the

(a) Geological Observations. Chas. Darwin, 2nd Edition, 1876, pp. 160-166.

corals of previous writers are calcified branches of trees, and the marine shells are identifiable with the recent land shells, observations which have a bearing upon the occurrence of oil in the formation.

Mr. H. Y. L. Brown, writing in August, 1872, in reference to what is evidently the same formation, stated :—

Along the coast, in a more or less broken line, on the southern and western coasts, never extending inland more than a few miles, there are hills and ridges composed of beds of calcareous grit, sandstone, and limestone, rising from below sea-level to a few hundred feet above it.

On the southern coast these occur only as patches, but on the western as an almost continuous strip, extending from Cape Leeuwin to the Murchison River and probably beyond. The presence of this formation appears to be due to the growth of coral reefs, upon which shells, sand, etc., have accumulated and become consolidated by the infiltration of water containing lime in solution. As a rule, the different layers of calcareous sandstone, limestone, etc., are horizontal, though often false bedded. They contain fossils, some of which are but little different from those now existing on the shores of the ocean surrounding this portion of the continent. (a)

And in 1892 Mr. H. P. Woodward reported :—

On the south side of Princess Royal Harbour, and from it to Torbay, a line of limestone hills forms the coastal range for a distance of about nine miles, whilst to the northward sandy and swampy flats with low ferruginous sandstone hills extend nearly as far north as Mount Barker, a distance of about 25 miles, spreading out to 15 or 16 miles in width between the Hay and Kalgan Rivers. In this large basin a bore has been put down 68 feet by Mr. Parry at Eastwood,  $7\frac{1}{2}$  miles on the railway from Albany, the property of Mr. Powell, when the following section was obtained:—

|                       |    |    |    |                   |
|-----------------------|----|----|----|-------------------|
| Sandy peat            | .. | .. | .. | 8ft. 6in.         |
| Ferruginous sandstone | .. | .. | .. | 1ft. 0in.         |
| Sand and black clay   | .. | .. | .. | 5ft. 6in.         |
| Quicksand             | .. | .. | .. | 5ft. 0in.         |
| Ferruginous sandstone | .. | .. | .. | ft. in.           |
| Quicksand             | .. | .. | .. | 30ft. 0in.        |
| Stiff black clay      | .. | .. | .. | 4ft. 0in.         |
| Quicksand             | .. | .. | .. | 10ft. 0in.        |
| Brown coal, quicksand | .. | .. | .. | 3ft. 0in.         |
| Total                 | .. | .. | .. | <u>67ft. 1in.</u> |

At this depth the bore most unfortunately fell in, so it still remains undetermined as to whether true coal measures do exist beneath this formation or not. The sample is of a dull sooty black colour, showing a good deal of vegetable structure. It is not highly mineralised but fairly compact, soft, friable, and soils the hand. The fracture is irregular, showing a laminated structure. It does not ignite readily, but when made red-hot it burns slowly, giving out a good deal of heat, and when ignited in a tube it gives off a small quantity of gas, tar, and water.

(a) On a Geological Exploration of that portion of the Colony of Western Australia lying Southward of the Murchison River and Westward of Esperance Bay. Perth: By Authority, 1873, p. 14.

An analysis yielded the following result:—

|                 |    |    |    |    |    |        |
|-----------------|----|----|----|----|----|--------|
| Water           | .. | .. | .. | .. | .. | 6.275  |
| Volatile matter | .. | .. | .. | .. | .. | 18.84  |
| Fixed carbon    | .. | .. | .. | .. | .. | 14.835 |
| Ash             | .. | .. | .. | .. | .. | 60.05  |

The percentage of water is low for a coal of this class, the volatile matter, consisting of luminous and non-luminous gases, is also low; so is the fixed carbon, whilst the quantity of ash is enormous. The coke was in the form of a fine sooty powder, whilst the ash was light, and of a creamy colour. It is of no commercial value. . . .

In the same report Mr. Woodward states :—

The hills along the South Coast are of two ages, those forming the main coastal range being the older. They consist of a series of limestones and shaley sandstones dipping at an angle of 40 to 45 degrees to the north-east, or under the flat in which the boring operations have been carried on. In these outcrops no organic remains were visible, but to judge from their dip, which is persistent for a distance of nine miles, they must be of considerable antiquity, as we know that very little disturbance has occurred in the Mesozoic Period.

At the south-east end of this range, and to the south of Princess Royal Harbour, the limestones are white, earthy, and contain fragments of hard cream-coloured limestone; but the sandy shales are entirely absent. Although these hills run in the same direction as those farther to the westward, they have no well defined bedding, and are probably the passage or junction beds between the Mesozoic sandstone, which outcrops all down the coast to the eastward, and the older rocks met with here. These Mesozoic sandstones make their last appearance on the side of Mount Clarence, which is on the north side of the harbour, where a sample obtained in sinking a well contained the characteristic fossils, but no fossils have yet been found in these rubbly limestones. . . . It is evident that a large basin, surrounded by granite, does exist, and that rocks, probably of Palaeozoic age, outcrop on its southern side (a). . . .

In the year 1900, a report upon boring for coal near Albany was prepared by myself, and full details given regarding the 16 bores which had been sunk in the vicinity. The deepest bore was carried down to a depth of 234ft., and in every case the floor of the older crystalline rocks upon which the beds were laid down was unequivocally reached. (b)

Princess Royal Harbour is about  $4\frac{1}{2}$  miles long in a direction of about north-west and south-east, with a width of about  $2\frac{1}{2}$  miles. The harbour itself is very shallow, and particularly so at its north-western end.

Lying to the south of the railway line, and between it and the coast, is a strip of low-lying land connecting the head of the harbour with Grassmere and Torbay Inlet.

There are very strong grounds for believing that Princess Royal Harbour and Torbay Inlet were at one time connected, and that the high ground extending from Limestone Head to Port Hughes formed

(a) General Report by the Government Geologist for the year 1892.  
Perth: By Authority, 1893, pp. 3 and 4.

(b) Annual Progress Report of the Geological Survey for the year 1900.  
Perth: By Authority, 1901, pp. 16-20.

an elongated ridge separated from the country to the north by a more or less extent of sea water.

Several bores have been put down in this low ground, and in every case was the floor of the older crystalline rocks met with, the greatest depth being 234ft. Full details regarding these bores can be found in the Annual Progress Report of the Geological Survey for the year 1900, pp. 16-20.

The high ground on the north side of the Princess Royal Harbour, including Mounts Adelaide, Clarence, Melville, and Elphinstone, is composed of granite of the type which occupies such a large area to the north. This granite is traversed by greenstone dykes, some of which can be seen on the beach near the gasworks.

The high ground upon which the Quarantine Station is built is also made up of granite; this granite also is traversed by numerous dykes of greenstone, many of which may be seen on the coast between Barker Bay and Mistaken Island. These dykes are pretty well all parallel, practically vertical, and have an average strike of about 101 degrees. Some of the dykes contain masses of granite, which have been caught up during the injection of the basic magma. The granite mass of the Quarantine Station extends south-east, and forms Mistaken and Seal Islands, and the rock underlying the more recent beds of Limestone Head.

On the south side of the harbour at Grave Head (Stuart's Head of Admiralty Charts) is a fairly extensive belt of granite which reaches down to sea level. This patch is separated by a comparatively thin cover of recent deposits from a much larger and more extensive area, which extends from Limekilns Point (Limeburner Point of the Admiralty Charts) to the summit of Snake Hill, 320ft. above sea level. At Limekiln Point the granite is overlaid by a thin belt of sandy limestone, which occupies a narrow strip round this portion of the beach. The limestone, which forms the summit and flanks of Snake Hill, extends southwards and forms the northern slopes of that high ridge which separates Princess Royal Harbour from the Southern Ocean. Granite was also met with in two of the bores (Nos. 1 and 2) put down in Princess Royal Harbour by the Mineral and Oil Company, at depths of 46ft. and 48ft. respectively. These two bores were put down near the north shore, not far from Melville Point (Testing Point of the Admiralty Charts). The old granitic floor was pierced at a depth of 109ft. in a bore a mile south of the Eastwood Railway Station, whilst at Torbay Junction, bottom was reached at 134ft., after passing through variable thicknesses of drift sand and clay.

The granite also makes its appearance again in great force in the high ground upon which the Trig. Station (470ft.) near Port Hughes has been erected. Stony Island, on the south coast, due west of Grove Hill and due south of Eastwood is also of granite.



These observations indicate perfectly clearly that the landlocked Princess Royal Harbour is merely a relatively shallow depression, resting upon a floor of ancient crystalline rocks. This fact is of importance in its bearing upon the possibility of mineral oil in the harbour.

From Port Hughes, at Torbay Inlet, to Limestone Head is a line of very high perpendicular limestone cliffs, which were carefully examined in two localities; these beds form most conspicuous features in the landscape, and in places are exceedingly picturesque, owing to the number of caves and caverns into which they have weathered. These beds rise to a height of nearly 700ft. above sea level. These limestones are aeolian deposits, consisting practically of shell sand, cemented in places into solid rock owing to the action of rain water.

The shell sand is converted into a limestone of sufficient hardness to ring like a bell when struck with a hammer; there are, in addition, several softer chalklike beds, which pass by almost insensible gradations into a very hard compact stone.

Landwards these aeolian deposits terminate in a more or less regular smooth bank or face, to which layer after layer is gradually added. The irregular current bedding of these deposits gives the appearance of limestones dipping at varying angles from the horizon, and apparently overlaid by nearly horizontal beds.

These aeolian deposits attain their greatest development on the sea coast to the south of Princess Royal Harbour. Isolated fragments and blocks of the chalklike limestone are occasionally dredged up in the harbour, along with piece of drift asphaltum, etc., of extreme origin.

A very recent formation occurs at many points round the harbour, and consists of a somewhat peaty ferruginous, partly consolidated, sand "associated with the formation carrying bitumen and traces of oil." At several places there exudes from this formation a compound of iron, which, when floating on the surface of the water, shows a play of prismatic colours, very often mistaken for those produced by some oils.

A scum of this kind can very easily be distinguished from that produced by oil in that the scum from an iron compound of this kind will readily break up into irregular fragments on being stirred but if of oil it will form bands of colour.

At times there may be seen floating about Princess Royal Harbour patches of an oily substance, which have been claimed to have been seen rising from beneath the water at several portions of the harbour, and to be an indication of an oil-bearing formation beneath.

A sample of this shown to me was associated with fine coal dust, and had the characteristic odour of machine oil, such as is in use in many of the steamers frequenting the harbour.

There is nothing in the geological constitution and structure of Princess Royal Harbour to in any way indicate that the occurrence of mineral oil is probable ; whilst the wrong hypothesis as to the source of the bitumen dredged up and the oil floating about on the surface of the water, appears to have led to money being needlessly spent in boring, etc.

A. GIBB MAITLAND,  
Government Geologist.

## 6.—Notes upon the Geological Map of the Greenough River District.

*(With a Map, Plate VI. and a Geological Section Plate V.)*

The area examined extends from near the Wizard Peak to Eradu, and includes the Minnenooka, Sandspring, and Tibraddon areas. The distance across in a direct line is about 18 miles, but by the course of the river it is about 45 miles.

Granite and garnetiferous gneiss forms the river bed from below Glengarry to the road crossing at Loc. 409, and extends from the base of Wizard Peak and of the adjacent flat-topped hills to Minnenooka and nearly to the Sandspring homestead, and northward to Tibraddon, and eastward from there to Wicherina Spring, about  $3\frac{1}{2}$  miles from Eradu; only three small diorite dykes were seen and very few quartz reefs. These crystalline rocks attain an elevation of nearly 1,000 feet in places. In other portions of the district they are overlaid by a series of sandstones and conglomerates, which are mostly horizontal, but have in places an inclination of about 4 degrees to the south. The upper 200 feet of these beds on the western escarpments of the granite have occasional argillaceous and marly bands, which are mostly fossiliferous, containing marine shells of apparently jurassic age; 250 samples of these fossils were collected, together with fragments of wood which occur in beds below or interstratified with the beds of marine shells.

The whole sedimentary beds vary greatly in character; they frequently exhibit current bedding, and are evidently shallow water deposits; some of the white sand rock or sandstones are saline; where this is the case there are argillaceous sandstones below them. The sandstones are frequently so ferruginous as to have the appearance of an ironstone, and laterite frequently occurs on their surface. This laterite is often difficult to be distinguished from the ferruginous beds themselves. The sandstones also form the sand plains occupying all the highest ground towards the north and east of the area described and beyond.

There appears to be a probability that there are two formations of different ages comprised in these sandstones, the older may be of permo-carboniferous, and the younger of jurassic age. The former was laid over the then submerged hills and valleys of the granite and gneiss rock, and may have become eroded towards the western slopes of the granite, and afterwards both were overlaid by jurassic sandstone.

The majority of the fossiliferous horizons occur in the uppermost beds and are often covered directly by laterite; but fossils appear to occur also over 100 feet below these, as in the valley above the Tibraddon homestead.

The accompanying general section (Plate VI.), which I have drawn, shows the extent of the information at present obtainable, while the map (Plate V.) shows the area coloured geologically in as much detail as the month at my disposal permitted.

No shale or coal beds were seen, but these may possibly exist at a lower depth than has yet been reached in the Greenough area by boring.

The brackish and saline character of the pools of that portion of the Greenough River below Beetalyianna Point appears to be due to the saline sandstone which occur below that point. A sample of water from one of the pools that was in process of being dried up. was obtained for the Analyst's examination. Springs are fairly plentiful in the granite area and afford good potable water. Good supplies of water have also been obtained by wells sunk 30 to 40 feet into the sandstone at Sandspring; at the latter place an excellent spring also occurs in the sandstone at that homestead, but elsewhere the well water is mostly brackish.

W. D. CAMPBELL,  
Assistant Geologist.

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NOTE.—For a list of the Champion Bay Jurassic Fossils, see page 60.

# Appendix I.

## LIST OF SPECIMENS IN THE GEOLOGICAL SURVEY MUSEUM FROM THE GREENOUGH RIVER.

| Reg.<br>No. |                                                                                                                |                            |
|-------------|----------------------------------------------------------------------------------------------------------------|----------------------------|
| 6661.       | Diorite, 1 mile south of Tibraddon Homestead,<br>crossing gully, Microscopic Section made ... ..               | 3 specimens                |
| 6662.       | Diorite, Loc. 492, in river bed below road crossing ...                                                        | several small<br>specimens |
| 6663.       | Aphanitic Diorite, $\frac{1}{4}$ -mile north of Quarry Hill and<br>1 mile south of Sandspring Homestead ... .. | 1 specimen                 |
| 6664.       | Granite, adjoining diorite dyke specimen 6661 ...                                                              | 1 specimen                 |
| 6665.       | Granite, 1 mile south of Tibraddon Homestead, in<br>gully ... ..                                               | 1 specimen                 |
| 6666.       | Granite, Wicherina Spring ... ..                                                                               | 2 specimens                |
| 6667.       | Graphic Granite, centre of Loc. 1236, Snake Farm ...                                                           | 3 specimens                |
| 6668.       | Micaceous Sandstone, near Loc. 492 ... ..                                                                      | 1 specimen                 |
| 6669.       | White Saline Sandstone, upper part of cleft near<br>Photo. 259 ... ..                                          | 3 specimens                |
| 6670.       | Sandstone, 2 chains north-east of Photo. 259 ...                                                               | 3 specimens                |
| 6671.       | Argillaceous bed in river cliff below specimen 6669 ...                                                        | 1 specimen                 |
| 6672.       | Ferruginous Sandstone, near Loc. 1236 ... ..                                                                   | 1 specimen                 |
| 6673.       | Stratified kaolinized granitic material ... ..                                                                 | 1 specimen                 |
| 6674.       | White Sandstone, near Loc. 1236, Snake Farm ...                                                                | 1 specimen                 |
| 6675.       | Fibrously crystalline siliceous bed, top of hill, west of<br>Loc. 492 ... ..                                   | 1 specimen                 |





## 7.—Recent Advances in the Knowledge of the Geology of Western Australia.

(Being the **PRESIDENTIAL ADDRESS** by A. GIBB MITTLAND, F.G.S., Government Geologist of Western Australia, and formerly of the Geological Survey of Queensland, delivered in Adelaide before Section C of the Australasian Association for the Advancement of Science, on the 8th of January, 1907.)

My first duty in assuming the position of the Presidentship of the section of Geology is to express to you my deep sense of gratitude for your confidence in my devotion to the welfare of our science implied in the election of one who, owing to the exigencies of official life, has had few opportunities during the last 19 years of becoming personally acquainted with the majority of the "Brethren of the Hammer" in Australia. The honour, however, is enhanced by the fact that in addressing the members of this section of the Association in Adelaide, I am speaking in the capital of a State which has contributed—in the persons of Messrs. H. Y. L. Brown and H. P. Woodward—so much to the progress of official geological research in Western Australia.

The civilising value of scientific investigation, such as is evidenced by a gathering of this kind, where the "hammerers" from the West meet those from East, upon common ground, for the purpose of discussing, consolidating, and recording the work of the past, must tend to link all parts of this continent together, and time perhaps will show that it may fall to the lot of the Australian men of science to materially assist in the solution of the problem of preserving those harmonious relationships and the strengthening of those ties which are so severely taxing the combined resources of political diplomacy.

It is, I believe, customary for the occupant of the Presidential chair to offer a few observations on some special department of the science which seems in his opinion worthy of attention, and I am therefore unwilling to depart from what must be regarded as traditional usage. On looking over the list of subjects reviewed by my predecessors in this chair, and the contributions of the different members read before this Section, I find few dealing with those portions of Australasia with which I am personally familiar, viz. :—Queensland, British New Guinea, and Western Australia.

After due consideration, therefore, I have chosen to invite your attention for an academic hour to a succinct account of the recent advances in our knowledge of the geology of the Western portion of this Continent, to the investigation of which my attention has been more immediately directed during the last decade.



In a broad and general way the geology of Western Australia offers many interesting points of analogy with that of South Africa and India.

In the present condition of our knowledge of the geology of the State, it is almost impossible to deal systematically with the various formations as a whole, for, owing to a variety of causes, geological inquiry up to the present has consisted merely of a series of unconnected observations, to the co-ordination of which we must look to the future ; nevertheless our observations have been so widely extended as to permit of certain broad generalisations.

Geologically the rocks of the State may, for the purpose of this address, be divided into three distinct groups, viz. :—

- (I.) The crystalline, schistose, and metamorphic rocks, a group the members of which have certain features in common, occupy definite areas, and various lines of inquiry point to being of considerable geological antiquity, possibly of Archæan Age, though in the present condition of our knowledge I prefer to adopt the term Pre-Cambrian.
- (II.) The sedimentary rocks which extend with many blanks from the Lower Cambrian to the most Recent ; and
- (III.) The volcanic rocks which are so largely developed in the northern portion of this State.

#### *I.—The Crystalline Schists and the Metamorphic Rocks.*

The Pre-Cambrian crystalline schists, and metamorphic rocks constitute the principal mineral region of Western Australia, and so far as is at present known, the area occupied by these venerable beds is about two-thirds of the total superficial extent of the State, which is 975,920 square miles. As our knowledge advances, however, this estimate of the area occupied by the Pre-Cambrian rocks may be subject to some modification.

There are probably few parts of this continent which can boast of a finer development of these older rocks than Western Australia, and perhaps no more promising field can be found for their investigation.

Considerable interest in connection with these rocks centres, so far as petrographical questions are concerned, in the translation of both the igneous and sedimentary formations into crystalline schists. Observations in the field point to the possibility of the mechanical movements to which the rocks have been subjected having modified or obliterated structural features previously impressed upon them, and that they may contain formations belonging to different geological systems. Sections in the Nullagine District show those beds to be made up of cleaved conglomerates some of whose pebbles consist of a pre-existing conglomerate from an earlier

series, of which no trace has yet been found. With a possible exception alluded to later on, it is important to note that this ancient metamorphosed sedimentary series, so abundantly represented in Western Australia, has yielded no fossils as yet.

If perhaps I dwell at a somewhat greater length upon these older rocks, it is that their economic importance has necessitated the attention of the Geological Survey, being up to the present, principally devoted to their investigation rather than to that of the strata lying uncomformably above them.

Time will hardly admit, though there is the inclination, of trespassing upon your time by affecting comparisons with the geology of similar areas of Pre-Cambrian rocks in other countries, nor discussing many of those theoretical questions arising out of the data which have been massed.

These older rocks have been studied in more or less detail in different localities throughout the State, distributed over fourteen degrees of latitude. They consist of rocks of very different types, many of them are in a crystalline condition, and form coarse crystalline schists and gneiss, which differ but little from granite and other rocks of like origin, as well as basic rocks, which have been more or less crushed, foliated, and completely converted into greenstone schists.

A very important feature of these basic schists is the presence among them of unfoliated rocks which sometimes occur in the form of lenticular belts of considerable extent, diabase, dolerite, diorite, epidiorite, pyroxenite, porphyrite, amphibolite, etc.

In some localities these basic rocks can be seen passing by scarcely perceptible gradations into hornblende schists, while in others are bands of magnetite schist, in the centre of some of which are large phacoidal-shaped masses of greenstone occurring in such a way as to indicate that the margins only of the masses have been ground down into schists.

Some of these older rocks are of sedimentary origin, and are practically unaltered; others are quartz, mica schist, and granulites, whilst these represent the two extremes there are intermediate forms which link them together. The less altered members of these older rocks make their appearance in many portions of the State; the rocks consist of a great variety of types of indurated slates, quartzites, and conglomerates, together with igneous rocks, some of which there are very good grounds for believing to have been originally lavas and ashes.

Many of these old crystalline rocks have been so altered as to possess characters which cannot be looked upon as original because many of them have lost, not only their individuality, but also their geological identities.

A remarkable and very noticeable feature of these older rocks in most localities in which they have been examined is those bands of laminated quartzites and jaspers (which often contain oxide of iron to such an extent as to warrant their being classed as iron ores). These extend as roughly parallel bands, sometimes several miles in length, in the form of attenuated lenses which, owing to their serrated ridges stand out in bold relief, thus acquiring a conspicuousness perhaps out of all proportion to their real stratigraphical importance. These beds vary from almost pure quartz through varieties of banded hornstone, jaspers of great beauty, to almost pure hematite.

In certain localities these jaspideous beds present a very brilliant appearance, due to the interlamination of red, white, and dark-coloured bands with intermediate varieties, the difference of colour being due to the occurrence of iron in the form of either limonite, haematite, or magnetite.

These bands are often intersected by numerous faults, which, in some districts, are of considerable economic importance, for it is along these fault lines, generally at right angles to the strike of the quartzites, that rich shoots of gold often occur. In some cases these iron-bearing jaspers attain a very great thickness, over 1,000ft., and have been very much plicated and contorted, whilst in places they have been faulted in a direction parallel to the strike. The fault fissures being often filled with a fault breccia of jasper recemented by secondary chalcedonic silica. In all cases these jaspers and quartzites are vertical or inclined at high angles. In many localities these quartzites and jaspers contain magnetite in such quantities to render the use of a compass in the vicinity almost impossible. These beds have been styled quartzites, a term implying that they are sedimentary; they are, however, not of detrital origin, numerous sections in many of the fields show them passing by almost insensible gradations into the enclosing basic schists, the whole appearance suggesting a gradual replacement of the original rock along lines of maximum compression, a foliation by silicification, in other words they represent a case of metasomatism on an extensive scale.

It may be of interest to note that these beds invariably occur in the basic schists, in intimate association with auriferous quartz reefs, and are at times themselves auriferous. In order that the present confusion arising through the want of a name to distinguish infiltration or metasomatic quartzites from indurated sandstone may be obviated, I hope some one may be able to suggest a convenient means of escape from possible civil war between the field man and the laboratory man to which the present unsatisfactory system of nomenclature rather tends.

In 1905 the various divisions of these older crystalline rocks as developed on the Norseman Goldfield, were carefully mapped

and investigated, the salient features of which may be briefly summarised. The staple formation consists essentially of a series of highly inclined sedimentary rocks estimated to reach a thickness, making due allowance for repetition by folding, of about 800ft.

No argillaceous slates appear to occur in the Norseman district, though associated with the metamorphic sedimentary rocks is a bed of very coarse conglomerate. Some of these ancient sedimentary rocks appear to have been permeated by secondary silica and oxide of iron to such an extent as to form very conspicuous bands of laminated quartzites and jaspers, which make a pronounced feature of the field. Associated with the metamorphic sedimentary beds of Norseman are a series of interbedded igneous rocks, some of which are distinctly amygdaloid, and although most of their original characters have been almost entirely obliterated, there seems every reason to believe them to be ancient lava flows, which were poured out at practically the same geological period as the associated sediments. In addition to these undoubted lava flows, there are a series of diorites and epidiorites, which seem to be interbedded with the former in such a way as to suggest the possibility of their being intrusive sills and dykes. These igneous rocks have been subjected to considerable dynamical alteration, and in places appear as mica and chloride schists.

Another very important feature in the geological structure of Norseman is the occurrence of a large number of quartz porphyry dykes which traverse the eastern portion of the field in a general north-west and south-east direction. These acidic dykes vary much in appearance, colour, and texture, the crystallisation in some cases being such that the rocks look not unlike somewhat fine-grained indurated sandstone. These acidic dykes contain crystals of pyrites, and are occasionally slightly auriferous. These dykes in all probability form the apophyses of that large granite mass which lies to the east of Norseman. There are, in addition, a few isolated veins and dykes of dolerite, one of which is seen intersecting the quartz reef in one of the mines. The newest igneous rock on the field is the intrusive norite, which forms an east and west range, varying from a mile to half a mile wide, and which extends in an uninterrupted line to Mount Norcott, about twelve miles to the east, and for a considerable distance both east and west.

The earliest observer in this district, Mr. S. Goezel, indicates on his geological sketch map of the Auriferous Region of Western Australia the greenstones and allies of Norseman as being of Paleozoic Age, whilst the micaceous and talcose schists of the same district are referred to the Archæan.

The crystalline rocks of the type just described may be traced as far as the Kalgoorlie Goldfield, the wealth of which, coupled with the skill which directs both the mining and the metallurgical opera-

tions, have raised Western Australia to the front rank of mining countries in the British Empire.

As is well known, the productive area comprises a relatively small block of ground, which, by reason of the richness of the lodes by which it is riddled, has become known throughout the world as the "Golden Mile."

This area includes the well-known "Great Boulder," "Ivanhoe," "Horseshoe," "Perseverance," "Oroya-Brownhill," "Associated," and "Lake View Consols" mines. The deepest shaft at present is the Great Boulder, which has reached over 2,000ft., while the greatest depth to which the lodes have been followed is over 2,000ft. The country laid open by mining for investigation as judged by the number of drives and crosscuts amounts to several miles, whilst the rocks have been riddled with bore holes in all directions and angles, thus affording opportunities for the scientific study of many of the rocks in critical localities, and in their relation to the ore deposits, such as are hardly found in any other single mining field of the globe.

The geological structure of Kalgoorlie is not of that extreme simplicity which at one time had been anticipated. The staple formation consists as at Norseman, largely of certain schistose rocks, some of which are distinctly of sedimentary origin. The sedimentary beds are represented by rocks, which range from soft shales to jasperoid slates, grits to flinty quartzite, fine conglomerates or breccias to fairly coarse boulder conglomerate.

In intimate association, with the sedimentary beds are a series of hornblendic rocks, but whether these occur in the form of lava flows or are intrusive is as yet by no means clear.

There are, however, in addition to these certain undoubtedly intrusive igneous rocks, sodafelsites and porphyrite.

Most of the rocks of Kalgoorlie appear to have been highly altered by dynamical causes, with an accompanying recrystallisation of their constituents; many of them have been carefully analysed and microscopically investigated in the laboratory of the Geological Survey and the results made available. Time will not admit of detailed reference being made to the deductions to be drawn from these investigations, beyond the fact that the "lode formations," for which the field is famed, consist of a series of almost vertical banded schists of lenticular habit, and apparently owe their origin to the dynamo-metamorphism of a plagioclase-augite rock. Many of these ore lenses are of great length, and in some cases of considerable breadth; at times however, the lateral continuity of the lenses is interrupted by overthrust and normal faults of very variable downthrow.

For a systematic study of the metasomatic history of the auriferous deposits, leading as such must do to the discovery of

facts which will materially guide scientific mining, Kalgoorlie offers few, if any, rivals in Australia.

So far as observations have, however, at present been carried there do not appear to be any scientific reasons for believing that the mines of Kalgoorlie have by any means reached the limits of ore deposition, or that the lodes will not prove as a whole productive in depth.

The Pilbara district (lat. 21 degrees) affords better and more continuous sections than are generally to be met with in any of the other districts which have yet been examined; it thus reveals geological structures which are not to be found in the more southerly districts, and on this account serve to throw light upon obscure points in connection with the geology of other districts. These sections furnish very important evidence regarding the terrestrial movements to which these older rocks have been subjected. The Pilbara district contains very large areas of granite, granodiorite and gneiss, which, however, are not the oldest rocks. In every case where their relation to the schists can be observed along the margin, it is seen that these granites are everywhere intrusive, having gradually eaten its way into and partially absorbed them, and several sections may be noticed in which the granite sends out tongues and veins into them. One of the best localities in which the relation of the granite to the metamorphic rocks is at the Wodgina tinfield, which is situated on the headwaters of the Turner River about 24 miles from Port Hedland. The districts consist of a series of metamorphic sedimentary and bedded igneous rocks skirting the margin of an extensive granite mass, several hundred square miles in extent. These sedimentary auriferous rocks are pierced by a multitude of granite veins which in this district are of considerable economic importance by reason of the fact that they form matrices of tin and tantalite, for which Wodgina is noted. Near the tinfield is an instructive section showing a much older intrusive granite rock, which has been invaded by the much newer (though still old) tin-bearing granite. These acidic veins are made up of a coarse-grained rock composed of mica, quartz, felspar, and now and then tourmaline, and may be described as pegmatite, using the term in the sense in which it was applied by Delesse for any coarse-grained granitic rock containing mica, quartz, felspar, and tourmaline. No reference to these old granitic rocks would be complete without some mention being made of the large ice-like quartz reefs, which stand up to considerable altitudes above the surface like a wall, and which can in some cases be traced across country, with more or less interruption, for miles. They may be described as veins or dykes of pure silica, in some of the mine workings in two fields veins of this character are to be seen cutting across the auriferous quartz reefs. The question as to the relationship of these acid intrusive dykes of the type just mentioned and these quartz reefs has recently been attracting con-

siderable attention, and there is a growing tendency to associate some quartz reefs genetically with pegmatite granite veins. In the Coolgardie Goldfield quartz reefs are often intimately associated with acidic dykes, and in some cases the latter gradually pass into pure quartz at their extremities. These acid dykes can be seen to pass by imperceptible gradations into the main mass of the granite at Coolgardie. Similar instances have been noticed in the Wodgina neighbourhood, and doubtless there are numerous other instances, but possibly they may have been overlooked, and their significance unappreciated.

Now a granite mass during the process of cooling gives rise to more acid pegmatite veins, and by further elimination of the bases pure quartz veins may result.

Various intermediate stages between granite and quartz veins have been noticed in Western Australia, and it is more than likely that many quartz veins are very probably intrusive rocks directly secreted from a cooling granite magma. Many pegmatitic granite veins contain tourmaline crystals as one of their essential constituents and many pure quartz veins in Western Australia contain tourmaline also.

Up to the present time, however, no observations have been made in this State with the object of discovering whether there are any of those structural and mineral changes induced in the enclosing rocks by the introduction of the quartz such as may often be observed consequent upon the injection of granitic veins. Observations upon this head, which are much to be desired, would have considerable scientific and even more important economic value.

In the southern portion of the State, the Darling Range, the Northampton District, etc., this fundamental complex is pierced by a much later series of basic dykes, where they sometimes preserve their dyke-like features across country without a break for miles. In the North-West district, however, they occur on a scale of magnificence as yet unknown in any other portion of Western Australia. Owing to the marked features which many of them exhibit these dykes can be readily followed across country, and in certain localities they are of considerable value in working out the details of the geological structures. A feature of significance is the faulting these later dykes have undergone since their injection and consolidation. In the Warrawoona field, an important North-West mining camp, these basic dykes traverse the centre of the auriferous zone almost at right angles to its general strike. The regular continuity of the system of dykes (which extend across country for 30 or 40 miles) has been interrupted in the vicinity of their intersection with the auriferous series, and they have undergone considerable movement since their injection. The peculiar dislocation and apparent displacement in short segments are probably due to a development of step-faulting in a manner not as yet

fully understood. The dykes are apparently cut into curved and distorted segments and displaced along more or less vertical planes which have a general tendency to shift the separate portions bit by bit, in one direction, the dykes being dragged to the north-west of their course.

A very important feature in the geology of the Pilbara District is the evidence of great earth movements that affected the district.

In the neighbourhood of the picturesque Doolena Gorge, on the Coongan River, very impressive evidence of a powerful rupturing of the crust is to be seen, represented *inter alia*, by a line of dislocation, which has been proved to extend for nearly 100 miles. The large quartz reefs to which allusion has just been made are seen to be abruptly cut off by this powerful fault, which presents a steep vertical escarpment (unscaleable in places) often over 150ft. in height. At some distance north of this main fault an instance was observed (on the eastern bank of the Strelley River) of one of these large reefs, being not actually truncated, though subjected to deflection by a powerful thrust, exerted in a direction approximately parallel to its strike. In this instance the compression has been so great that this very reef, which is about 30ft. thick, was reduced to six to 10 inches, whilst the horizontal displacement reached about 100ft.

The quartz reefs of the district also afford evidence of over-thrusting, contortion, etc., and many of them present features which seem to indicate that they have been wrenched apart by movement along shear planes. A very important instance of this is to be seen at the mining camp of Warrawoona, where a line of reef of a peculiar type traverses the field along a powerful dislocation, which has been followed for two and a half miles.

This dislocation occurs along a persistent reef, portions of which have been torn apart and shifted in segments, producing the peculiar kidney or damper-shaped lenses of quartz, which vary from a few inches to a foot or so in width. The interval between each lens of quartz fluctuates within very wide limits.

The walls of the country enclosing these lenses are scored with striae in the direction of the movement in a vertical direction, and the faces of the striations are often coated with fine films of gold. The abnormal richness, nearly 30zs. per ton, of this type of auriferous reef has resulted in its being extensively prospected almost along the whole length, hence abundant opportunities are afforded of investigating its peculiarities, both on the surface and below ground.

The ancient sedimentary beds, which consist of highly siliceous rocks, dipping at varying angles to the north and east, consist of fine-grained flaggy quartzites, conglomerates, and quartz schist.



Some of the conglomerates still retain traces of their original character, though in others most of the pebbles have been flattened out and stretched almost beyond recognition.

The oldest series of basic dykes, by which they are traversed, have also been crushed and sheared, and are now represented by bands of schistose greenstones. The rocks are also intersected by certain other acidic dykes now represented by quartz-sericite schist, which may have originally been porphyries. One example from Warrawoona is a quartz sericite schist with "eyes" of a fairly soft mineral, originally a potash felspar, around which the fine foliation of the matrix sweeps in very graceful curves. When submitted to microscopic examination it is found that these porphyritic crystals present that peculiar peripheral granulation so characteristic of crystals and fragments which have been subject to intense crushing.

All the features, both of the rocks and the reefs, coupled with other evidence, clearly indicate the presence of a number of overthrust and normal faults, and point to a series of movements along lines parallel to that of the main trend of the dominant structural features of the district, which is north-west and south-east. The disruption of the newest series of basic dykes to which reference has been previously made, indicates that the enormous terrestrial stresses and strains continued in the same locality over a wide interval of geological time.

Traces of life may perhaps have existed in these old rocks of the north-west. Amongst the quartz schists which form the lofty serrated summit of the main axis of Warrawoona is a bed which here and there contains what at first glance appears to be fossil wood.

A characteristic specimen of this silicified wood (?) has a length of about  $4\frac{1}{2}$  inches; cross-sections of it are ellipsoidal in shape, the major axis being about  $\frac{3}{4}$  and the minor axis about  $\frac{5}{8}$  of an inch in length.

Microscopical sections, both transverse and longitudinal, were prepared and submitted along with the specimens to Mr. Etheridge, of the Australian Museum, who, however, was unable to detect any trace of organic structure in them. It is, however, quite possible that some form of organic life existed at the time these beds were deposited, and that the marked changes which they have undergone obliterated all traces of organic structure.

## *II.—The Sedimentary Rocks.*

The sedimentary rocks, etc., include the whole of the beds which lie between the ancient crystalline rocks and the more recent strata. In spite, however, of the extensive area occupied by the complex of crystalline schists, Cambrian fossils have been as yet noticed from only one locality in the far North of Western Australia.

Mr. E. T. Hardman, of the Geological Survey of Ireland, was the pioneer geological observer in the far North of Western Australia, and his researches carried out in the years 1883 and 1884 laid the foundation of our knowledge of the geology of the Kimberley District. This observer, however, obtained fossils from some limestones which have been referred to the Cambrian.

In 1891 Mr. H. P. Woodward made an extensive examination of the Kimberley District, and added considerably to the observations of Mr. Hardman.

Ten years later, in 1901, in company with Mr. Chas. G. Gibson, Assistant Geologist, I made a series of investigations in the King Leopold Plateau when searching for a reputed goldfield on the Carson River, between the 15th and 16th degrees of latitude.

In the latter part of 1905, and the early months of 1906, Dr. Jack visited Kimberley for the purpose of inquiring into the possibility of artesian water being obtained in the district.

Mr. Woodward revisited Kimberley in the winter of 1906, and examined the country between Mount Broome and the coast on the west, in the vicinity of Collier Bay, and obtained *inter alia* a trilobite from a dun-buff coloured limestone. The trilobite, which has just been submitted to Mr. Etheridge, appears to very closely resemble *Olenellus*.

Mr. Woodward describes these limestone beds as dipping at angles varying from 12 to 23 degrees to the south-west. The basal beds, consisting of limestone and conglomerate, contain fragments and boulders of the schistose and granitic rocks which unconformably underlie them. This observation is of importance in that, with the specific determination of the fossils he collected, light may be expected to be shed upon the age of the crystalline schists.

We thus have a good many details regarding the geology of this far north region, though as our knowledge has advanced it cannot be said that the tangled skein has yet been unravelled.

In the course of his investigations, Mr. Hardman gathered a suite of fossils which were critically examined by Mr. R. Etheridge and Mr. W. H. Foord and Dr. Henry Woodward.

Among the *dissecta membra* were the head and spine of a trilobite belonging to the characteristic Cambrian family, *Olenellus Forresti* and numerous pteropods, *Salterella Hardmani*, from a locality which, unfortunately, cannot now be identified. The discovery of the locality from which *Olenellus* was obtained by Mr. Hardman may be expected to go a long way towards setting at rest much that is at present puzzling regarding the geology of Kimberley.

Dr. Jack, writing in February of 1906, regarding the locality of *Olenellus Forresti*, says:—

The fossils described by Mr. Foord in his Notes on the Palaeontology of Western Australia (Geol. Mag., March and April, 1890),

were collected by Hardman in 1883, and presented by him to the British Museum in 1886. Hardman's trip of 1883, described in his first report (1884), extended from Derby to the Leopold Range. Hardman's label on the trilobite in question was:—"River South of Base-line."

There are two base-lines on Hardman's maps: (F9-EB) at Mt. Campbell (Lat. 18.13) (Long. 125.30), and the other (WE-EB) at the Hardman Range (Lat. 17.40) (Long. 128.50). If the *Olenellus* was collected in 1883, the base-line referred to must have been F9-EB since Hardman could not, in 1883, have mentioned a line which was not laid down till 1884. On the other hand, there is no river "South of Base-line" F9-EB within the limits of Hardman's work, unless Christmas Creek be meant.

There is a "river" (Hardman, in Irish fashion, called all small watercourses "rivers") viz.: the Turner, south of Base-line WE-EB. It washes the south-west side of the Hardman Range, but a good deal farther from the range than Hardman's map gives it. The Base-line WE-EB could only be the one referred to on the supposition that Foord's information as to the date of the discovery was erroneous—that "1883" should read "1884."

But the limestone indicated in this case is classed by Hardman as the lower member of his Carboniferous formation, and I saw what is, no doubt, its continuation resting on a considerable thickness of beds of basalt, which lie on the upturned "Devonian" of the Albert Edward Range."

*Olenellus* is Cambrian.

Altogether, we are confronted by so many contradictory conditions that I am inclined to conclude that the fossil must be ignored as having come from a locality unidentifiable.

Despite the fact of poor localisation of Mr. Hardman's fossils, it may, I think, be taken for granted that Cambrian beds do occur somewhere in Kimberley about south latitude 18 degrees. The recent discovery of *Olenellus* and *Salterella* in the limestones of the Daly River, in the northern territory, by Messrs Brown and Basedow, is of considerable geological importance, indicating a somewhat wide distribution of Cambrian strata, and makes the solution of the Hardman puzzle almost imperative, and more especially so in the light of Mr. Woodward's recent discovery in the Napier Range.

By far the largest area of the Kimberley division is occupied by a formation which extends from Mount Hopeless, near Collier Bay via Mounts Hart, Broome, the Mueller, Saw, and Deception Ranges, Goose Hill, near Wyndham, to the South Australian border. These beds, which rest with a violent unconformity upon the crystalline schists, were provisionally referred by Mr. Hardman to the Devonian. Considerable confusion has arisen, as has recently been pointed out by Dr. Jack in a report on the Kimberley district now going through the press, in consequence of a discrepancy between the first and second reports of Mr. Hardman, in which he describes what recent observations have shown to be the same formation, first as Cambro-Silurian, or Cambrian, and later as Devonian.

These Devonian beds of Kimberley have yielded the following fossils : *Atrypa reticularis*, *Rhynchonella pugnus*, an *Orthoceras*, and two species of *Goniatites* and *Spirifera*.

A feature of interest and importance in connection with these beds is the evidence they afford of widespread contemporaneous volcanic activity. This was first noticed by Mr. E. T. Hardman in 1883 and 1884, who describes contemporaneous dolerites, volcanic breccias and tuffs. It has been suggested that some of the igneous rocks occur in the form of intrusive laccolites.

In the year 1901, Mr. Gibson and I had abundant opportunities of investigating these beds during six months spent in the exploration of what may be called the King Leopold Plateau. Our observations extended from Wyndham to Mount Hart, near Collier Bay; the Prince Regent and Glenelg Valleys—rendered almost classical by the researches of Sir George (then Lieutenant) Grey, more than 70 years ago—and as far north as Admiralty Gulf. The result of the investigations indicated that the staple formation was made up of a series of quartzites, sandstones, fine conglomerates and shales disposed in a series of broad anticlinal folds. These beds extend as one continuous formation from Mt. Cockburn to Mount Hart, a prominent summit on the King Leopold Range. Associated with the quartzites, etc., are a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase. The individual characters of the different beds naturally present a large amount of variation; the rocks are sometimes amygdaloidal, and contain nodules of zeolites and agates. Beds of volcanic ash and breccia are common in certain localities.

In certain isolated portions of the district excellent sections are exposed, showing the intrusive nature of some of the igneous rocks; the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of the igneous rock. Other sections indicate quite clearly that the igneous rocks have, in some cases, found an easy passage along the bedding planes of the sedimentary rocks and evidently occur in the form of sills.

The lavas are traversed by almost vertical dykes of epidosite, which are traceable across country for long distances, whilst both the sedimentary and the igneous rocks are intersected by numerous segregation veins of quartz, some of considerable size and horizontal extent.

Mr. Hardman noticed during his explorations in 1883-4 the association of fossils of carboniferous affinities, with those characteristic of the Devonian rocks in the Kimberley beds. Dr. Jack noticed in 1906 a similar association of Devonian and Carboniferous fauna from the beds near Mount Pierre, and makes mention of the carboniferous limestone region, consisting partly of limestones of an older date, and remarks that either there are in the Mount Pierre

region separable carboniferous and Devonian strata, or the same strata contain a Devonian-carboniferous fauna. It is possible that this apparent admixture of Devonian and carboniferous fossils may have been brought about by post-carboniferous orogenic movements of which there is abundant evidence in different portions of the State.

Three field seasons spent by myself in the Pilbara Goldfield, situated in latitude 21 degrees south, afforded an excellent opportunity for examining a formation consisting of sandstones, grits, conglomerates, and limestones, some of which are magnesian, together with a series of lavas, ashes, and agglomerates of as yet unascertained thickness. In its lithological characters, its behaviour and general physical aspect it bears a very strong resemblance to the quartzites, etc., of the King Leopold Plateau, to which reference has just been made.

This formation, which has been designated the Nullagine series, has a very wide distribution in the North-West, and the associated volcanic beds occupy a large area of country in the southern portion of the district. The series, which presents a plateau-like appearance, certain of the harder beds standing out in bold relief, presenting mural faces at different levels, plays a very important part in the geology of the North-West, in addition to being of some economic value by reason of the fact that the basal conglomerate of the series has been worked for the gold it contains in two widely separated localities, viz :—Nullagine and Just-in-time.

The Nullagine beds have been followed from the Oakover River across the upper reaches of the Nullagine, Coongan, and Shaw Rivers, as far as the western boundary of the Pilbara Goldfields on the Yule River, near Cangan Pool, from which locality they can be followed without a break to the vicinity of Roebourne. The same series constitutes the Hamersley Range, which contains Mount Bruce, the highest summit in the State. The Nullagine beds are probably continuous as far south as the Ashburton River, where both flanks of the valley are formed by extensive beds of magnesian limestone, which may be continuous with those which I observed in 1905 in the recesses of the Hamersley Range.

Regarding the southern extension of the Nullagine series it may be noted that in a deep bore put down by the Government at Onslow, near the mouth of the Ashburton River, volcanic rocks identical with those in the former district were met with. It may thus be that these strata were pierced in the lower portion of the Onslow bore.

Undoubted Permo-carboniferous rocks are known to occupy a large area of country in the watersheds of the Gascoyne, the Minilya, and the Lyndon Rivers, hence the examination at present being undertaken of the country lying between Onslow and Lyndon should afford some valuable information as to the mutual relations of the

Permo-carboniferous and the Nullagine beds. So far as observations have at present been carried there seems to be a gradually ascending geological series as we proceed southwards. What I am inclined to regard as outliers of the Nullagine series occur in the Murchison Goldfield, near south Latitude 27 degrees. In 1904 Mr. Gibson mapped a considerable portion of the auriferous belt of the Murchison, and described a series of fine-grained volcanic ashes, lying almost horizontally on the granite of Mount Yagahong, about two miles south of the townsite of Gabanintha. The beds have evidently a wide extent in the Murchison. At the town of Cue, some distance to the south of Gabanintha, there is a horizontal dolerite sheet capping what is known as Cue Hill, and some little distance to the west on the lower ground are a few outliers of quartzite on a lower horizon. These quartzites evidently form part of a much more extensive formation of which they are but remnants left. There is very little doubt that these beds form part of the same series as the volcanic ashes at Gabanintha.

The igneous rocks associated with the series consist generally of acidic lavas. The great mass of the rocks consist of separate lava flows, each of no great thickness; some of the lavas are distinctly amygdaloidal, the cavities being filled with chalcedony.

Some of the finer-grained ashy beds differ very little in general appearance from many of the banded lavas with which they are associated.

Undoubted volcanic focii, from which these lavas emanated, occur in many parts of the districts, though they have been extinct long enough to allow the process of weathering to reduce them to mere stumps. There are also several acidic dykes which pierce both the sedimentary and the volcanic rocks, and these in all probability represent but another phase of that extraordinary volcanic activity which occurred in the northern portion of Western Australia during the Devonian period.

Considerable interest attaches to the Nullagine series by reason of the nature of the boulder beds at the base of the formation; for two important scientific reasons, viz. :—(a.) the occurrence of flattened and striated pebbles to which a glacial origin has been assigned; and (b.) the nature of the gold and iron ore in the conglomerate.

The basal conglomerate of the series is made up of rounded, ellipsoidal, or subangular fragments of the older underlying series. Many of these often include pieces which reach a length of three or four feet. Some portions of the conglomerate contain flattened and striated pebbles of fine-grained sandstone and sandy shales, identical in character with those constituting the underlying strata. To these striated pebbles a glacial origin has been assigned by the late Mr. S. J. Becher, and subsequently by Professor David. The pebbles, however, seem to have had their striation induced

prior to their taking part in the formation of the Nullagine series. The beds upon which the series rest, and to the denudation of which the boulders owe their origin, having, as has already been shown, been subject to intense mechanical deformation, it would only be natural to find some slickensided fragments and pebbles in newer rocks. Earth movements have caused the Nullagine beds to be thrown into a series of undulatory folds, but the deformation thus induced has not been of sufficient intensity to cause any striation of the Component pebbles.

Such mining operations as have been carried out in the auriferous conglomerate have been, up to the present, confined to relatively shallow depths along the outcrop ; the conglomerate is in part marked by the presence of large quantities of iron pyrites and its oxidation products. In the inoxidised portion the pyrites occur both as crystals, grains, and rounded or pebble-like forms. A certain interest attaches to the occurrence of these rounded pebbles and pellets of auriferous pyrites and hematite on account of the fact that they have been regarded as owing their shape to attrition, and that the gold and the iron are detrital, having been deposited with the pebbles of the conglomerate, as the result of all disintegration of the underlying auriferous rocks. The evidence respecting the origin of the gold in the Nullagine conglomerates indicates that it is a secondary and not an original constituent, and further, that the primary source of the gold is the quartz reefs which occur in the underlying formation.

From the known occurrence of auriferous quartz reefs, which furnished no small portion of the pebbles of certain portions of the deposit, it is of course quite conceivable that a certain amount of detrital gold forms part of the conglomerate, but there are obviously no means of ascertaining what is the proportion of primary to secondary gold.

There seems, however, good reason for believing that by far the greater bulk of the gold, together with the pyrites, was introduced by solution percolating down to the most porous portions of the conglomerate, the condition being facilitated by the downward inclination of the bed rock, and possibly accentuated in part by the folding which the strata have undergone.

One of the most important advances in Western Australian geology is the recognition of a glacial conglomerate in the marine carboniferous rocks, near the tropic of Capricorn.

The carboniferous rocks of the State cover a wide extent of country, and bid fair to become of considerable economic importance.

The occurrence of Carboniferous rocks would seem to have first been made known through Sir George (then Lieut.) Grey in the year 1841, in his journals of the two expeditions of discovery in

North-Western and Western Australia during the year 1837-9. There are four districts in which fossiliferous Carboniferous rocks are known in the State, viz.:—Kimberley, the Gascoyne, the Irwin River, and the Collie Districts.

The Carboniferous rocks of Kimberley have recently been investigated by Dr. Jack, when in quest for artesian water. This observer's work was carried out in the months of December and January during one of the most severe droughts experienced in the district, and with a temperature often reaching 114 degrees Fahrenheit. Despite the fact that the route followed in investigating these beds, has perforce to be governed by considerations of grass and water, our knowledge of the Carboniferous rocks of Kimberley has been greatly extended. The formation is divisible into a lower or limestone series (in which limestone predominates) and an upper sandstone series (made up largely of sandstones and other sedimentary beds). The two series have been seen to succeed one another conformably in the Haughton Range, south latitude 19 S. and East Long. 127 E. Both series have yielded an assemblage of purely Carboniferous fossils:—*Lepidodendron*, sp.; *Stigmaria*, sp.; *Stromatopora concentrica* (?) *Stromatopora placenta*, sp.; *Pachypora tumida*; *Zaphrentis*, sp.; *Syringopora* sp.; *Actinocrinus*, sp.; *Platycrinus*, sp.; *Poteriocrinus crassus*, Miller; *Pentremites*, sp.; *Serpula*; *Spirobis*, sp.; *Fenestella plebeia* (antiqua,) McCoy; *Productus giganteus*; *Produstus longispinus*; *Productus semireticulatus*; *Chonetes*, sp.; *Chonetes Hardrensis*; *Discina*; *Orthis resupinata*; *Strophalosia Clarkei*, Eth. fils; *Rhynchonella pugnus*; *Rhynchonella pleurodon*; *Rhynchonella cuboides*; *Orthotetes crenistria*, Phillips; *Streptorhynchus crenistria*; *Terebratula hastata* (?) *Terebratula sacculus* (?) *Pleurotomaria*, sp.; *Toxonema*, small sp.; *Natica*, sp.; *Ceripora*, sp.; *Chaetetes tumidus*; *Stenopora Tasmaniensis*; *Cyathophyllum*, sp.; *Cyathophyllum virgatum*; *Cyathophyllum depressum*; *Lithodendron affine*.

So far as observations on the Kimberley Carboniferous rocks have been carried, no boulder beds have yet been recognised, though in view of the occurrence of glacial conglomerates in India within 18 degrees of the Equator their presence in Kimberley would cause little surprise. The necessity for a further more or less detailed geological examination of a portion of the Kimberley district is at the present moment under consideration by the Government, and the solution of the many economic questions involved in the stratigraphical research which such an investigation entails is of no less importance to the community than the purely scientific results which of necessity follow.

The Gascoyne beds cover a very large area between the 22nd and the 26th parallels of South Latitude, and excellent sections of them may be seen in the valleys of the Wooramel, Gascoyne, Lyons,



Minilya, and Lyndon Rivers. Like their representatives in Kimberley, the strata are divisible into an upper or sandstone and a lower or limestone series. The sandstone series, which is seen resting conformably upon the limestone, is well exposed in the Carandibby, Kennedy, and the Moogooloo Ranges, making a bold outcrop of almost 200 miles in length. The beds forming these ranges were, until quite recently, regarded as of Mesozoic Age. The discovery, however, of *Spirifera*, *Athyris* (?) *Productus*, and *Strophalosia* in the Kennedy Range, near Trig. Station K 37, on the northern bank of the Gascoyne River, definitely sets at rest the conflicting views until quite recently held regarding their position in the geological time scale.

The country to the east of the Kennedy Range is underlaid by fossiliferous beds of the limestone series, associated with which is the glacial boulder bed.

This bed, which forms a valuable stratigraphical horizon, has been traced across country for a distance of about sixty or seventy miles.

At the most southerly locality at which the boulder bed has been detected in Wooramel Valley, the boulders are of very large size, and is composed of rocks identical in character with those forming the older underlying rocks to the east, *e.g.*, granite and other crystalline and metamorphic rocks.

Some distance northward on the Wyndham River is a boulder bed in the limestone series. The bed, which at this spot attains no greater thickness than three feet, is crowded with boulders and pebbles of granite and crystalline rocks embodied in a calcareous fossiliferous matrix; a photograph of a specimen of which contains fragments of *Spirifera Productus* and *Polyzoa*, in addition to *Aviculopecten tenuicollis*, will be found in the Annual Report of the Geological Survey for 1900. The pebbles and boulders have a large proportion of smooth and polished faces. The flats in the neighbourhood are covered with boulders and blocks of crystalline rocks evidently derived from the weathering *in situ* of the conglomerate which has a dip of about three degrees to the south-west. In the bed of the Wyndham River beds of flaggy sandy limestone are to be observed passing beneath the boulder beds indicating what is perfectly obvious from numerous sections that the glacial conglomerate does not lie quite at the base of the Carboniferous rocks.

Associated with the boulder beds of the Wyndham River are the following fossils:—*Hexagonella dendroidea*, Hudleston sp.; *Pleurophyllum Australe*, Hinde; fragments of *Crinoid* stems, and *Polyzoa*; *Spirifera Musakheylensis*, Davidson; *Spirifera Hardmani*, Foord; *Spirifera lata*, McCoy; *Reticularia lineata*, Martin sp.; *Athyris Macleayana*, Eth. fl.; *Chonetes Pratti*, Davidson; *Productus* (cf *Pteuni-straitus*, Foord).

Northwards from the Wyndham River the *débris* of the boulder bed makes its appearance in great force. The flaggy sandstones immediately underlying it are covered with large boulders of crystalline rocks. Near Barragooda Pool, on the Arthur River, a thick bed of limestone directly overlies the boulder bed. This limestone has yielded the following fossils :—*Evactinopora crucialis*, Hudleston ; *Rhombopora tenuis*, Hinde ; *Athyris Macleay* and Eth. fil Var. ; *Productus semireticulatus*, Martin ; *Aulos-teges*, sp. nov. ; *Dillasma*, sp. ind.

A few miles to the north of this, near Trig. Station K. 34, the Carboniferous beds are faulted against the older crystalline rocks which, in this locality, consist of quartz and mica schists, associated with either dykes or sills of porphyry.

In the southern branch of the Minilya River, near Trig. Station K. 49, the boulder bed is seen overlying beds of limestone and shale. The *débris* of the boulder bed consists of a heterogeneous collection of all sorts of crystalline and metamorphic rocks, and contains numerous ice-scratched pebbles ; photographs of several typical examples appear as Plate IV. of the Annual Report of the Geological Survey for 1900.

It may be mentioned in this place that in a deep bore put down by the Government at Pelican Hill, near Carnarvon, that these Carboniferous or Permo-carboniferous beds were met with beneath fossiliferous Mesozoic rocks at 1,406ft., and continued to 3,011ft., the present depth of the bore. The Carboniferous strata are represented by calcareous shales and limestone. The cores from the bore have yielded *Spirifera*, *Aviculopecten*, *Anthracopectera*, and *Favosites*. The bore, however, which did not pierce the whole thickness of the Carboniferous rocks gave no signs of the boulder bed. From the few salient features pointed out it appears quite clear that the glacial conglomerate is associated and interbedded with the fossiliferous limestones low down in the Carboniferous series as developed in this part of Australasia.

In the year 1897 I made a traverse up the Murchison valley in an exceptionally dry season, which seriously interfered with geological investigation, and at a point in the bed of the river, about 100 miles south of the boulder bed last mentioned, a conglomerate and breccia composed of angular fragments of a quasi-vitreous quartzite dipping at a low angle to the east was met with ; the base of the conglomerate was not visible anywhere, the most important and significant feature in this section is the fact that many of the pebbles were covered with scratches, not unlike slickensides.

A few yards lower down the river are a few beds of cross-bedded sandstones and fine conglomerates dipping east at an angle of about 20 degrees. One of the beds has been scored to such a degree as to produce surfaces as smooth and polished as plate glass.

The question arises, is this portion of a glaciated pavement, or is it due to faulting? If the latter, the faulting is nearly horizontal. Some distance further up the river, near the Forty Mile crossing and water reserve 1005, the sedimentary beds are inter stratified with coarse conglomerates or boulder beds; the boulders are principally quartz, though pebbles of sandstone and granite occur. I detected no scratched boulders in this section, though circumstances did not admit of any detailed search being made. The important point in connection with these conglomerates containing the scratched boulders is that they form part of what is at present believed to be the southern extension of the Carboniferous series of the Gascoyne, and form a connecting link between the latter and the Irwin River series, to which reference will be made later.

Beneath the Jurassic rocks of the Champion Bay District and in the valley of the Irwin River and its tributaries is a fairly extensive development of Carboniferous and Permo-carboniferous beds. In this district, as in Kimberley, it is possible to divide the strata into two distinct series, viz., the lower, or limestone, and the upper, or sandstone series.

Beneath the Irwin River coal seams are a calcareous shale and limestones, yielding a series of fossils, which have been carefully examined and described by Mr. Etheridge, of the Australian Museum, and will shortly appear as one of the Bulletins of the Geological Survey of Western Australia. The following fossils occur in these beds :—

*Nubecularia, Stephensi*, How ; *Pleurophyllum Australe*, Hinde ; *Fenestella fossula*, Lons. ; *Dielasma*, sp. ; *Seminula subtilita*, Hall ; *Spirifera*, sp. ; *Reticularia lineata*, Martin ; *Productus semireticulatis*, Martin ; *Productus tenuis-triatus*, var Foord Eth. fl. ; *Productus undatus*, DeFrance ; *Productus subquadratus*, Morris(?) ; *Chonetes Pratti*, Dav. ; *Aviculopecten Sprenti*, Johnston ; *Conocardium*, sp. Brom. ; *Stutchburia*, sp. Eth. fl. ; *Bellerophon costatus*, J. de C. Spy.

*Gastrioceras Jacksoni*, sp. nov. (the largest goniatite yet found in Australia, and of an entirely different type to the incomplete forms so far described).

The facies of these fossils is more akin to the Carboniferous than the higher Permo-carboniferous, and only four species are with certainty identical with those found in the Permo-Carboniferous rocks of Eastern Australia, viz. :—*Nubecularia*, *Productus subquadratus*, *Fenestella fossula*, and *Aviculopecten Sprenti*.

Associated with the marine series is a boulder bed, the *débris* of which strew the surface for a considerable distance, but there has as yet been no opportunity of investigating these beds in any detail. So far I have seen no striated pebbles among the boulders.

About 25 miles lower down the river, in the vicinity of Mingenew, and close to the railway line, are a series of ferruginous sandstones, on a higher horizon than the limestones, which remind one very forcibly of the sandstone series as developed in the Kennedy Range of the Gascoyne River. These beds have yielded the following fossils :—

*Dielasma nobilis*, sp. nov. ; *Dielasma hastata*, Dana ; *Spirifera*, sp. ind. ; *Spirifera avicula*, E. B. Spy ; *Cyrtina carbonaria*, var. Australasica, Eth. fl. ; *Cleiothyris Macleayana*, Eth. fl. ; *Productus Subquadratus*, Morris ; *Productus brachythoerus*, E. B. Spy ; *Chonetes*, sp. ind. *Dellopecten subquinguelineatus*, McCoy ; *Modiola* (?), sp. ind. ; *Myalina* (?) *Mingenewensis*, sp. nov. ; *Fenestella* or *Proloretopora*.

On the whole, it seems that the aspect of the fossils is that of the Permo Carboniferous of New South Wales.

It thus seems that there are in the Irwin River valleys beds of Carboniferous and Permo Carboniferous Age, and that the coal seams may possibly be the equivalents of the Greta Coal Measures of New South Wales.

The Collie River beds, which attain a thickness of a little over 2,000ft., are of considerable economic importance by reason of the fact that they contain coal seams to a total thickness of about 137ft., and are of some scientific interest in their relation to the important question of the distribution of the *Glossopteris* flora.

The Collie River coal field lies to the east of Bunbury and south of Perth, north-western edge of the tableland which succeeds the coastal plain. The field itself is traversed by the Collie River at an altitude of about 600ft. above the level of the sea. The area occupied by the Collie River coal measures is approximately 500 square miles. The beds consist of alternations of shales, sandstones, and grits, which rest directly upon granite schist and other crystalline rocks. The boundary of the field is, with one local exception, everywhere defined by faults ; on the south-western side of the field the boundary fault has been estimated to have a down throw to the north-east of at least 2,000ft.

There are several coal seams in the field of variable thickness, they consist in descending order of Cardiff No. 1, seam 9ft. to 12ft. thick.

Cardiff No. 2 or Boulder Seam, 7 feet thick.

Collie Burn No. 1 Seam, 9 feet thick.

Collie Burn No. 2 Seam, 6 feet to 7 feet 10 inches thick.

Coal (no name), 8 feet thick.

Proprietary No. 1 Seam, 4 to 8 feet thick.

Proprietary No. 2 Seam, 5 feet to 7 feet 6 inches thick.

Walsend Seam, 9 to 17 feet thick.

The coal seams are hydrous, semi-bituminous, non-caking coals, which approach very closely to lignite in some parts; between the

various varieties the differences are only of degree for there are no distinctive characters which would find universal application. Owing to the conditions of deposition the coals naturally vary in character, and in places pass insensibly through forms containing a large proportion of earthy matter into carboniferous shales.

The question of the precise geological age of the Collie River beds is one about which there has been, and still is, considerable divergence of opinion.

In the year 1891, Mr. H. P. Woodward, the Government Geologist, assigned an early Mesozoic Age to the beds, basing his determinations principally upon the physical aspect of the field, and the chemical composition of the coals.

A little later some fossils were submitted to the late Mr. R. Etheridge, sen., who detected *Glossopteris* or *Neoggerthia*, and concluded that the beds were Permo Carboniferous.

In 1894, Mr. Woodward, basing his opinion upon the results of Mr. Etheridge's determination, referred the beds to the Upper Carboniferous.

In 1897, Mr. E. F. Pittman, Government Geologist, New South Wales, visited Western Australia, and in a report, referred the strata to the Mesozoic, on the strength of Mr. Etheridge's (jun.) doubtful recognition of *Sagenopteris*.

Upon a geological map accompanying a report by myself, published in 1898, the age of the beds was defined as uncertain.

In 1898, Sir Frederick McCoy reported the discovery of *Glossopteris Browniana* in some fossils sent to him by the Premier of the State, and stated that the beds were of "the exact geological age of the great coal fields of Newcastle, New South Wales." I may add, however, that these fossils were not collected by, nor were they ever seen by, any member of the geological staff.

Mr. R. Etheridge, jun., in his "Notes to accompany a miscellaneous collection of Western Australian fossils," submitted to him by myself in 1903, recognised undoubted *Glossopteris* in a good state of preservation, from the Moira Colliery, and constrained him to support the age assigned to the Collie River beds by his father, viz., Permo-Carboniferous. Mr. Etheridge carefully examined the *Sagenopteris* (?) obtained by Mr. Pittman, and in the same report abandons his previous determination, and now looks upon it as *Glossopteris*.

In 1904 Dr. Jack received a Commission from His Excellency the Governor to fully investigate all aspects of the Collie coal industry, including *inter alia* geological conditions. Accompanying the Commissioner's Report is an excellent geological map and

longitudinal section ; upon the former the age of the Collie River beds is set down as undetermined. Dr. Jack in his report says:—

The evidence bearing on the age of the Coalfield is at best inconclusive. High authorities have indeed expressed the opinion that it was of Palæozoic Age—Carboniferous, or Permo-Carboniferous—but all these opinions are founded exclusively upon the presence of the form *Glossopteris*, which is now known to range from Carboniferous to late Cretaceous. The shales are coarse-grained and incoherent, and badly adapted for the preservation of plant remains.

Dr. Jack draws attention to the fact that the various beds in the series are less coherent than is customary among the Carboniferous or Permo-Carboniferous formations of Europe, Africa, and Australia, and concludes :—

In a somewhat wide experience I have seen nothing which the Collie Coal Measures, coal seams included, so much resemble as the Oligocene Coal Measures of Croatia. While eagerly looking forward to the production of further evidence and open to conviction, I am at present inclined to believe that the Collie Coalfield will turn out to be possibly of Cretaceous Age, newer than the Coalfields of Ipswich and Burrum of Queensland.

The next and perhaps most important evidence bearing upon the controverted question is contained in some "Notes on fossils from the Collie Coalfield, Western Australia," in the "Collection of the National Museum, Melbourne," by Mr. F. Chapman, the Palæontologist to the Natural History Museum, Melbourne, just about to be printed as one of the Bulletins of the Geological Survey of Western Australia.

This writer recognised the plants :—*Glossopteris browniana* ; *Glossopteris browniana* var *indica* ; *Glossopteris browniana* var *communis* ; *Glossopteris browniana* var *angustifolia* ; *Glossopteris browniana* *gangamopteroides*.

And in the associated sandstones the following Foraminifera :—*Endothyra* ; *Valvulina plicata* (U. Carb. List, England) ; *Bulimina* (Permo-Carboniferous, N.S.W.) ; *Truncatulina haidingeri* (Permo-Carb., N.S.W.) ; *Pulvinulina exigua*.

The *Valvulina* of Collie, though very much dwarfed, is essentially a Carboniferous form whilst the other species Mr. Chapman detected and described point in a general way to the Palæozoic Age of the series.

Mr. Howchin pointed out in 1893, in his "Census of the Fossil Foraminifera of Australia," that the Australian Palæozoic foraminifera show a closer affinity with the Permian fauna of the Northern hemisphere than the Palæozoic.

In view of all the evidence at present to be deduced from the plant remains and the marine organisms in the beds associated with the Collie coal seams, despite the nature of the coal and the physical characteristics of the basin, I am constrained to admit that a Permo-Carboniferous Age of the series presents the strongest claims to

acceptance. I make no excuse for the fact that my present views on this much debated question are not those I previously held, but our most cherished opinions, like everything else, must yield to that stern logician—fact.

Jurassic rocks have been found up to the present in only one district—that of Champion Bay, near Geraldton; but the beds have not been investigated in any detail by the Survey, hence our information about them is at the best somewhat meagre.

Mr. Crick, of the British Museum, in a paper on “A Collection of Jurassic Cephalopoda, from Western Australia,” records *Ammonites (Perisphinctes) Championensis* from Cape Riche, to the East of Albany, and naturally claims a Jurassic Age for the beds.

In 1898 I visited Cape Riche. The beds consist of sandy limestones, which extend between Cape Riche and Warriup, and are fossiliferous. The Cape Riche beds have yielded:—Impressions of a Cycadaceous leaf (?) *Hemiastrer*, sp.; *Pectunculus*, near *P. flabellatus*; Ten. Woods, internal casts of *Cytherea*, *Arca*, *Lima*, *Macra*, *Amusium* and *Voluta*, in addition to *Venus*, near *V. Voseo-tineta*, Baird.

The Warriup beds have yielded:—*Cardium*, sp.; *Cardium hemicardium*, Linn; *Trochus personatus* (?) Phil. and *Arca reticulata*, G.M. These strata would therefore seem to be either recent or very young Tertiary. Even assuming that the Cape Riche series turn out on further investigation to be Secondary, I do not think the Jurassic can put in any claim for recognition. I am, therefore, inclined to think that Mr. Crick's *Ammonite* recorded from Cape Riche has been wrongly localised, and really came from Champion Bay.

The Champion Bay Jurassic beds cover a fairly large area of country to the south in the neighbourhood of the coast line; they are seen to rest with a violent unconformity on the Carboniferous rocks of the Irwin River valley. They also probably extend northwards, for in the deep bore near Carnarvon strata high up in the Mesozoic series have been recognised, between 1,200 and 1,500 feet.

The Champion Bay beds consist of oolitic limestones, clays, sandstones, grits, and conglomerates. Fossils are abundant, and they include a considerable number of Cephalopoda:—*Belemnites*, sp.; *Nautilus perornatus*, sp. nov.; *Ammonites (Dorsetensia) Clarkei*, sp. nov.; *Ammonites (Stephanoceras) Australe*, sp. nov.; *Ammonites (Sphaeroceras) Woodwardi*, sp. nov.; *Ammonites (Sphaeroceras) semiornatus*, sp. nov.; *Ammonites (Perisphinctes) Championensis*, sp. nov.; *Ammonites (Perisphinctes) robinginosus*, sp. nov. There have also been obtained:—*Trigonia Moorei*, Lycett, *Myacitus Sandfordii*, Moore; *Lima*, sp.; *Lima* allied to *L. pectiniformis*, Gold; *Cucullaea semi-striata*, Moore; *Pleuromya*, *Astarte Cliftoni*, Moore; *Cresslya*, sp.; *Gryphaea*, sp.; *Mytilus* allied to *M. Cygerensis*, D'Orb; *Pecten frontalis*, Dumortier.

No estimate can as yet be made of the thickness of these Jurassic beds; they have, however, been pierced by four bore holes in the Champion Bay district, the deepest being at Dongara. This bore was sunk for the purpose of the delimitation of the seaward extension of the Irwin River coal measures, which there are good grounds for believing to lie beneath the Mesozoic beds. The bore attained a depth of 2,111 feet when operations were stopped owing to the capabilities of the boring plant being exhausted without the base of the Jurassic rocks having been reached. There are thus over 2,000 feet of these beds in this locality.

The recognition by Mr. W. D. Campbell of the remnants of an extensive dolomitic limestone formation at an altitude of about 900 feet above the level of the sea at Norseman, and distant about 100 miles due North from the coast at Esperance Bay (Long. 122 degrees East) containing fossils of either late Tertiary or Recent Age is, perhaps, next to the Carboniferous Glacial beds, one of the most important of the recent advances in our knowledge of the younger geological formations.

Two small outliers of this formation occur on the western bank of Lake Cowan and four near Lake Dundas. The beds, which in the vicinity of Norseman occupy but a very small area, consist principally of a dolomitic limestone, with several siliceous bands. These beds contain species of *Turitella*, allied to *T. terebra*; *Pecten*, *Cardium* (or *Cardita*) *Magellania*, and fragments of *Polysoa*. These discoveries are of considerable importance, and must be thoroughly examined some day, as they involve a whole series of important conclusions which depend upon the age of the fossils the beds contain.

At Balladonia, many miles to the east and in what is known as the Eucla limestone plateau, the flesh coloured limestones have yielded:—A *Pecten*, allied to *Chlamys asperimus*, Lamck; near Madoura Station a shell agglomerate yielded *Venus peronii* var *conularis*, Lamck; and *Tapes*, probably *T. Avaneosus*, Phillipsi, a living species. These fossils seem to indicate a deposit of comparatively recent age.

Entering the State at its eastern frontier in the Nullabor Plains, and extending without any interruption as far as Israelite Bay, is very large development of strata of Recent and Tertiary Age. These strata consist of flesh-coloured limestones associated with sandy porous beds, into which the rainfall is rapidly absorbed and discharged seawards in the form of fresh water springs, and are the western extension of the beds pierced in the five bores in South Australia.

These beds form what is known as the Premier Downs. An immense limestone plateau extending from Goddard's Creek (E. Long. 124 degrees) to the South Australian frontier, terminating abruptly along its southern border by a conspicuous escarpment



400 feet high in some places. The limestone plateau extends for miles into the interior, and the average altitude (so far as can be ascertained) of the inland margin is about 1,000 feet above sea level.

The bore nearest the Western Australian frontier is at Albalakaroo, on or near the telegraph line at about 45 miles east of Eucla. This bore attained a total depth of 1,084 feet, and bottomed on granite at 1,073 feet, after passing through (in descending order) 565 feet of (Eucla) limestone, 426 feet of clay (shale), and 82 feet of a "hard rock," which those in charge of the operations could not determine.

Two bores have been sunk by the Western Australian Government near Madura. No. 1 bore was put down at a point 110 feet above sea level, and distant 30 chains south of the Eucla limestone escarpment, which is 350 feet high. The bore was carried down to a total depth of 2,041 feet, and passed (in descending order) through about 766 feet of limestone, underlaid by alterations of clay shale, sometimes Glauconitic dolomitic limestone. The bore ended in a soft mudstone. The second or No. 2 bore was situated 30 miles to the north of No. 1, on the limestone plateau, and about 300 feet above the level of No. 1. It was carried down to a depth of 412 feet, and passed through nothing else but limestone—the Eucla limestone. The sequence of strata in the Western Australian bores coincides in its essential particulars with that indicated by the South Australian bores, and there can be very little doubt as to identity of the two series of beds whatever may be their age.

*Laterite.*—No mention of the recent advances in Western Australian geology would be complete without some reference to that extensive development of residual deposits which have been found over the whole length and breadth of the State.

The term laterite has been officially adopted, though in a somewhat more extended sense than its original application, for all the deposits resulting from the decomposition and reconsolidation of rocks *in situ*.

The laterites of Western Australia consist largely of hydrated oxide of iron and alumina, producing on the one hand deposits of excellent iron ore and on the other bauxite. In some parts of the State the deposition of secondary silica in the lateritic deposits produces what are practically quartzites; these, by an increase in the ferruginous colouring matter, pass into a jasperoid form of laterite. There are thus three forms of these laterites—an aluminous, a ferruginous, and a siliceous—the composition being liable to vary considerably over a small area, it being largely governed by the nature of the underlying rocks.

The structure is sometimes massive and almost homogeneous, but is more frequently pisolitic and nodular, in which case the concretions are richer than the interstitial matter.

The lateritic deposits naturally vary in their lithological characters. They are often very porous and weather into caverns and cavities of all sizes. The surface of the rock is often covered with a glaze of hydrated oxide of iron. When freshly broken the rock presents a mottled appearance owing to the different shades of brown, yellow, and red. The rock passes gradually into the underlying rocks without any sharp line of demarcation. That ferruginous and siliceous laterites are more commonly met with is due to the fact that deposits of this type are better able to resist disintegrating influences than the softer varieties; they thus not only remain themselves, but act as a protecting cover for the rocks beneath.

Mr. J. Beete Jukes, writing in 1850, in his almost classic "Sketch of the Physical Structure of Australia," mentions the occurrence of these lateritic deposits as seen by him in the country between Perth and York. He says :—

For a few feet below the surface the rock was a singular concretionary ferruginous compound which looked like a clay or sandstone that, being highly ferruginous, had formed itself into a mass of small balls and irregular concretions of a black oxide of iron or hematite. Below this ironstone (which is its name in the Colony) wherever the rock was exposed it appeared for many miles to be granite or some granitic compound.

In another place he mentions as occurring in one of the lateral valleys of the Swan River—

A thin capping of ironstone forming a line of small crags.

In 1861 the late Mr. F. T. Gregory gives in his paper "On the Geology of a part of Western Australia," an account of this lateritic deposit capping, the Darling Range, and claims for it a Devonian Age. This observer mentions the important fact that the deposit blends gradually with the upper surface of the granite, and states that it would seem to owe its origin to the decomposition of the granite *in situ*.

The Rev. W. B. Clarke, in his "Sedimentary Formations of New South Wales," remarks :—

Mr. F. T. Gregory indicated on his map and in his report the existence of Devonian Rocks near York, and in other parts of that Colony. Having examined the rocks so indicated, I can only state my belief that they have no pretension to any such antiquity and are probably mere collections of loose granitic matter, and other drift cemented by ferruginous paste, which has since become transmuted into concretionary nodules and hematite. There are also pebbles of trap, much decomposed in the so-called Devonian. They may be perhaps more properly considered as representing the Laterite of India.

It is on these historical grounds that Laterite has been adopted in Western Australia as the name for these residual deposits rather than the term Saprolite, which American writers have suggested.

The various reports of the Geological Survey contain numerous descriptions of these lateritic deposits, and are often accompanied by analyses.

These analyses show variations in alumina from 7.52 to 44.66 per cent. ; ferric oxide, 10.02 to 88.23 per cent. ; silica, 1.53 to 23.26 per cent. ; combined water, 8.10 to 26.44 per cent. ; and oxide of titanium, .59 to 3.10 per cent.

A recent analysis of a ferruginous laterite from Comet Vale (North Coolgardie) is of interest

On account of the high percentage of chromium, mostly in the form of a hydrate readily soluble in hydrochloric acid, the balance being present in the form of chromite.

The analysis gave 79.01 per cent. of ferric oxide, 5.30 per cent. of chromic oxide, 3.14 per cent. of silica, and of water 12.35 per cent. Some of the laterites have proved to be more than appreciably auriferous.

In the southern portion of the State where the rainfall is greatest, the lateritic deposits support an abundant vegetation. The well-known karri and jarrah growing in all their splendour thereon. In fact the mapping of the lateritic deposits of this portion of the State would define the areas over which both karri and jarrah occur.

Elsewhere in the State the laterites support but a scanty vegetation.

So far as our observations have been extended the laterites, for the reason previously given, occur as disconnected outliers, which once formed part of a continuous deposit. It is difficult to escape the conviction that since they were deposited, a considerable time may have elapsed, hence the laterites may be of some geological antiquity of which possibly the thickness and the state of consolidation may be some measure.

We have, however, as yet, little authentic evidence on this point, though it may be mentioned that a bore put down at Coolgardie, on Reserve No. 23, certain plant remains were found in a deposit containing what is evidently the detritus of the lateritic beds. These plant remains have, on examination, been held to belong to the *Eucalypti*. McCoy has described definite eucalyptus foliage from the older gold drifts in Victoria, whilst Ettinghausen describes several species from the Upper Tertiaries of New South Wales and deep lead in the New England Tinfield.

On this evidence, therefore, the laterites seem to be of earlier age than the Tertiary, though there is but little doubt that lateritic deposits are forming at the present time.

### III.—Volcanic Rocks.

Volcanic rocks have played an important part in the geological history of Western Australia, and the evidences of this igneous ac-

tivity are to be found in the form of lava flows, ash beds, breccias, dykes, stills, etc., which make a prominent feature in certain portions of the State.

Many writers and observers, it must be noted with regret, treat volcanic rocks in such a fashion as to suggest that they constitute a more or less meaningless interpolation in geological history, and I have no desire to be included in the same category.

There are, so far as is at present known, three distinct periods in which Western Australia has been the scene of igneous activity of more or less intensity. These periods are :—

- (a.) In Pre-Cambrian time, prior to the deposition of the beds containing the *Olenellus* fauna. These old igneous rocks are of importance in the part they appear to have played in connection with the formation of the ore deposits of the State. These have been more or less fully described in the opening portions of this address.
- (b.) A period commencing early in the Nullagine (Devonian) time, but ceasing before the Carboniferous. The interstratification of lavas and ashes with the sandstones and conglomerates point to subaqueous eruptions, though from the amygdaloidal nature of many of the lavas, the bulk of these volcanic rocks must, I think, be sub-aerial. Several of the focii from which the lavas, etc., emanated, have been noticed. The magnificent series of basic dykes of the North-West and elsewhere, to which reference has already been made, suggest to one who has examined the Devonian Volcanic Series, that fissure eruptions, of which these dykes may form part, have been in some way responsible for the wide extent of the lava flows, which cover some hundreds of square miles.
- (c.) After the deposition of the Jurassic Beds, and believed to be of Tertiary Age, they consist of basic lavas and ashes, which occur in great force in the Kimberley District.

In the Ord and Bow River valleys these lavas appear to have levelled up the depressions formed therein (except certain knife edge ridges of the older rocks, which still protrude above the level) and in places rest upon the Devonian Volcanic plateau. On the Behn River, just above what is known as the "Gorge," Dr. Jack noted a dome or "pug" of basalt, which apparently formed the focus from which some of these lavas issued.

At Bunbury, and one or two points on the coast round the south-west corner of the State, bedded columnar basalts occur. Over large areas, and far into the interior, numerous volcanic eject-

menta, in the form of obsidian bombs occur, and were probably derived from volcanoes of which no trace has yet been found, it is quite possible they may owe their origin to that volcanic region which skirts the northern coast of Australia.

The geological age of these basaltic lavas in the present state of our knowledge is a matter for inference only, but if we assume that they all belong to one period, they must be set down as Tertiary.

Some of the basic intrusive dykes, which are also widely distributed in the North-West, and form such pronounced features in the scenery, belong to a later period, that of the volcanic eruptions of Nullagine (Devonian) times; for many cases have been noticed in which they traverse the Nullagine Beds for many miles. Since the Nullagine volcanic fires became extinct Western Australia appears to have known no outbreak of igneous activity until pretty well Tertiary times.

The history of volcanic action in Western Australia is thus the history of Pre-Cambrian, Devonian, and the Tertiary periods.

It is hardly possible within the scope of a single address to consider the whole question of the Geology of Western Australia. My object has been to point out what light has been thrown thereon through recent investigations, by merely touching the fringe of the subject, and my task has now been completed.

In the fulfilment of the task I have endeavoured to inflict to the full that punishment which, by the irony of fate, seems to be the recognised method by which a President conveys his appreciation of being made the recipient of one of the highest honours which his scientific brethren have within their power to bestow.

Whether or not I anticipate your endorsement of or disagreement with the verdict that the "Punishment fits the Crime," I *know* that I am voicing your feelings when I say that during our efforts to wrest from Mother Earth those secrets which are graven in mystic characters on her face, we geologists by merely wandering over the surface, exchanging the genial sunlight for the feeble flicker of the miner's candle, peering down the tube of the petrological microscope, calling to our aid the delicate chemical balance, or poring over the "Medals of Creation" in the seclusion of the Museum Cabinet, re-echo the sentiments of one of Germany's greatest poets and thinkers.

"Ach, wunderschön ist Gottes Erde!"

"Und schön auf ihr ein Mensch zu sein."

A. GIBB MAITLAND,

Government Geologist.

## 8.—Prevention of External Corrosion of Goldfields Water Supply Pipes.

### (a.) PRELIMINARY REPORT.

*Nature and Causes of Corrosion.*—Before any suggestions could be made for the prevention of external corrosion of the Goldfields Water Supply pipes, it has been necessary to ascertain beyond doubt the causes of the corrosion, and as the result of experiments made, the following conclusions have been drawn:—The corrosion of steel in this case, as in most others, consists in the formation of a porous impure hydrated oxide of iron, rust, at the expense of the solid metal, owing to the interaction of the latter with water, and the oxygen dissolved by it out of the air, or otherwise derived. More particularly rust has been shown recently by Dr. Moody in a paper to the Chemical Society to consist mostly of the ferric hydrate,  $\text{Fe}_2\text{O}_3 \cdot (\text{HO})_x$ , with more or less small proportions of ferrous hydrate  $\text{Fe}(\text{HO})_2$ , and ferrous carbonate  $\text{FeCO}_3$ , a result borne out by the experiments carried out by Dr. Earp and myself upon the rusting of the metal of the Goldfields Water Supply pipes, of which more anon.

It may be taken as an axiom that no chemical action can take place at ordinary temperatures between two permanent and dry solids, owing to the inertness of the molecules in the solid state, and to the impossibility of establishing sufficiently intimate connection between them. The presence of a third substance in the liquid or gaseous state, which is capable of dissolving even traces of either substances, sets up a condition of affairs very much more favourable to chemical action, since the dissolved molecules are in a far more active state than before, and intimate connection is assured per medium of the liquid or gas, whilst, most important of all, electro-chemical action may also come into play.

One other fundamental fact must be noted. The most modern researches in chemistry have established the fact that in very many cases of chemical action the most important (chemical) factor is not the overwhelming proportion of the two main substances acting, but those apparently insignificant traces of other substances, which either profoundly alter the nature of the main materials, or else, in ways still obscure in many cases, more or less greatly enter themselves into the chemical actions going on and retard or accelerate them.

All these considerations bear directly upon the subject of this research, viz., the cause of the more or less rapid corrosion of the external surface of mild steel pipes laid underground. For, in the first place, we may assume without hesitation, that perfectly dry soil in contact with perfectly dry pipes, whether coated or not with any form of paint, would not cause the pipes to corrode. Steel will undoubtedly corrode to a very slight extent if suspended in

air out of reach of rain or other visible moisture, since even the driest air contains water in solution, and thus three essentials to the formation of rust, viz., water, oxygen, and carbonic acid, are in contact with the steel. Such corrosion is undoubtedly extremely slow (except when, owing to the proximity of burning coal, sulphurous acid vapours exist in the air), and is reduced to an infinitesimal amount by coating the metal with any relatively inactive and impervious material, such as an asphaltic or graphite paint. The asphaltic paint (tar, asphalt, and maltha) used in coating the Water Supply pipes seems to have been, where not removed by rough handling, etc., very impervious and closely adherent, and therefore an excellent preservative. The corrosion from air is quite negligible therefore.

A much more active cause must be looked for, and failing air, this was sought for in the soils. A number of these have been examined, and more still being analysed with the greatest care, owing to the interesting results obtained up to the present. The soils consist for the most part of quartz sand, clay, and iron oxide in varying proportions. There is very good reason for believing that none of these main constituents exerts any chemical influence on the pipes. Vegetable matter is practically absent. Two causes of corrosion suggested themselves, viz. :—

1. The presence of pyrites in the soil undergoing oxidation in the presence of water and air with the production of sulphuric acid. Except possibly in one case, this was proved not to be the case since pyrites were absent, and on treatment of the soils with water the solution far from being acid was found to be alkaline, owing to the presence of carbonate of lime.
2. The presence of moisture in the soil, associated with an electrolyte (or substance capable of carrying an electric current) in the form of a salt of some strong mineral acid. In the light of the experiments made, there appears to be no doubt that this is the main, if not the sole cause of the corrosive effects observed.

Recent experiments in England have shown that :—

- (a.) Chemically pure water is without effect upon iron or steel, such water being practically a non-conductor of electricity.
- (b.) The addition of pure oxygen to chemically pure water does not make it more active towards iron.
- (c.) The further addition of an electrolyte of the kind mentioned, such as common salt, gypsum, etc., sets up galvanic action, resulting in the formation of free acid and consequent active corrosion.

The electrolytic decomposition of an oxygen salt, such as a sulphate or carbonate, liberates at one pole (the anode) free oxygen

together with the free acid corresponding to the salt, viz., either sulphuric or carbonic. The similar decomposition of a chloride yields chlorine in solution, an energetic solvent for iron. It is evident, therefore, that if any plate, or portion of a plate of iron or steel becomes the anode in the presence of a solution of such an electrolyte, energetic corrosion of that plate is to be expected.

The very modern science of metallography has shown that steel in common with most other commercial metals, is not a perfectly homogenous substance, but a mixture of two or more alloys. In the case of mild steel of the nature used in these pipes, the internal structure is found to be a main mass of "Ferrite," which is almost chemically pure iron, and embedded in this mass numerous small grains of "Cementite," a carbide of iron ( $\text{Fe}_3\text{C}$ ), more or less regularly distributed. In these two constituents of the steel plates we have the necessary poles and connections to form, when in contact with a solution of an electrolyte, a series of small batteries, each causing corrosion.

Ferrite is a highly electro-positive substance, and therefore dissolves with comparative rapidity. Cementite is more electro-negative, and being also the cathode is but little affected by the action. That this electrolytic effect is not so small as one might at first expect is shown by the use to which it is put in determining the constituents of iron and steel by the etching of polished surfaces.

To obtain a rough quantitative idea of this action a series of experiments has now been made, using relatively pure water and solutions in water of the various electrolytes normally occurring in soils. A number of small bars, 3in.  $\times \frac{3}{4} \times \frac{1}{4}$  were cut from the metal of which the pipes in question are made, and roughly polished, these were then put in an upright position into well-stoppered bottles, and covered for half their depth with the following liquids:—

1. Distilled water, freshly boiled to remove all oxygen and carbonic acid.
2. Distilled water that had been standing some days and had probably absorbed considerable oxygen and carbonic acid from the air.
3. Distilled water saturated with carbonic acid.
4. Freshly boiled distilled water saturated with calcium carbonate (0.01 per cen. solution).
5. Do. with magnesium carbonate.
6. One per cent. solution of sodium bicarbonate.
7. Do. of calcium chloride.
8. Do. of magnesium chloride.
9. Do. of sodium chloride.
10. Saturated solution of calcium sulphate.
11. One per cent. solution of magnesium sulphate.
12. Do. of sodium sulphate.
13. Solution containing  $\frac{1}{2}$  per cent. each of magnesium chloride and sodium nitrate.



14. Do. sodium chloride and sodium nitrate.
15. One per cent. solution of sodium nitrate.
16. Water extracts of soil No. 1926.
17. Do. of No. 1962.
18. Do. of No. 1963.
19. Do. of No. 1924.
20. Do. of No. 1957.
21. Do. of No. 1956.

The results of these experiments were extremely interesting, in every case but one a noticeable amount of corrosion had taken place within the space of an hour, as shown by the formation of rust on the surface of the plates, and the appearance of a precipitate or deposit of iron oxide in the solutions surrounding them. The effects were watched for two days, when the steel bars were removed, and the iron removed from them was estimated.

These experiments show that :—

- (1.) Rusting takes place in comparatively pure water containing a little oxygen and carbonic acid.
- (2.) That the amount of rust formed is nearly double in the presence of a little common salt, sodium carbonate, or a mixture of magnesium chloride and sodium nitrate; whilst it is considerably increased in the presence of a little calcium carbonate, chloride or sulphate, magnesium sulphate, sodium sulphate, or nitrate. All these salts occur in the soils examined.
- (3.) Water extracts of three soils where the pipes were said to be very bad yielded nearly double the amount of rust yielded by pure water.

This being so, the soils were examined with a view to determine the nature and quantity of the soluble salts contained in them. The following table gives the results in percentages of the soil :—

| Laboratory No. ... ..      | 1835                                  | 1812                                | 1814                               | 1815                               | 1816                     |
|----------------------------|---------------------------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------------|
| Locality, miles and chains | 17-35                                 | 128-72                              | 122-20                             | 129-68                             | 183-00                   |
| Condition of pipes ... ..  | Bad                                   | Bad                                 | Fair                               | Very Good                          | Good                     |
| Calcium carbonate...       | ·014                                  | ·002                                | ·038                               | ·002                               | ·025                     |
| Magnesium „ ... ..         | ...                                   | ·019                                | ...                                | ·020                               | ·038                     |
| Sodium „ ... ..            | ...                                   | ·015                                | ...                                | ·014                               | ·014                     |
| Calcium sulphate ... ..    | ·083                                  | ...                                 | ·002                               | ...                                | ...                      |
| Magnesium „ ... ..         | ...                                   | ...                                 | ·040                               | ...                                | ...                      |
| Sodium „ ... ..            | ...                                   | ·025                                | ...                                | ·013                               | ·178                     |
| Sodium nitrate ... ..      | ...                                   | Trace                               | ·019                               | Trace                              | ...                      |
| Calcium chloride ... ..    | ·037                                  | ...                                 | ...                                | ...                                | ...                      |
| Magnesium „ ... ..         | ·037                                  | ...                                 | ·003                               | ...                                | ...                      |
| Sodium „ ... ..            | ·076                                  | ·082                                | ·200                               | ·034                               | ·355                     |
| Iron oxide and alumina ... | ...                                   | ...                                 | ...                                | ...                                | ...                      |
| Silica ... ..              | ·010                                  | ·032                                | ·015                               | ·020                               | ·014                     |
| Total ... ..               | ·207                                  | ·176                                | ·317                               | ·103                               | ·538                     |
| Nature of soil ... ..      | Weathered<br>diorite and<br>grey clay | Coarse,<br>grey, very<br>sandy clay | Light<br>brown, very<br>sandy clay | Light<br>brown, very<br>sandy clay | Buff, very<br>sandy clay |

| Laboratory No. ... ..      | 1961.            | 1962.              | 1963.                  | 1964.            | 1966.            |
|----------------------------|------------------|--------------------|------------------------|------------------|------------------|
| Locality, miles and chains | 183-17           | 192-00             | 201-16                 | 216-06           | 218-40           |
| Condition of pipes ... ..  | Good             | Good               | Fair                   | Bad              | Fair             |
| Calcium carbonate ... ..   | .011             | .014               | .028                   | .025             | .025             |
| Magnesium " ... ..         | ...              | .002               | .004                   | .023             | ...              |
| Sodium " ... ..            | ...              | ...                | ...                    | .006             | ...              |
| Calcium sulphate ... ..    | .034             | ...                | ...                    | ...              | .023             |
| Magnesium " ... ..         | .025             | .082               | .024                   | ...              | .056             |
| Sodium " ... ..            | .070             | .061               | .050                   | .085             | .034             |
| Sodium nitrate ... ..      | ...              | ...                | ...                    | ...              | ...              |
| Calcium chloride ... ..    | ...              | ...                | ...                    | ...              | ...              |
| Magnesium " ... ..         | ...              | ...                | ...                    | ...              | ...              |
| Sodium " ... ..            | .266             | .009               | .018                   | .240             | .163             |
| Iron oxide and alumina ... | .028             | .034               | .013                   | .013             | .011             |
| Silica ... ..              | .013             | .006               | .016                   | .038             | .010             |
| Total ... ..               | .457             | .158               | .153                   | .488             | .320             |
| Nature of soil ... ..      | Brown sandy clay | Yellow clayey sand | Light grey, sandy clay | Brown sandy clay | Light brown clay |

| Laboratory No. ... ..      | 1966.            | 1970.                 | 1971.           | 1972.            | 1971.          |
|----------------------------|------------------|-----------------------|-----------------|------------------|----------------|
| Locality, miles and chains | 241-01           | 267-70                | 306-70          | 313-40           | 315-40         |
| Condition of pipes ... ..  | Fair             | Good                  | Fair            | Fair             | Bad            |
| Calcium sulphate ... ..    | .025             | .009                  | .025            | .036             | .025           |
| Magnesium " ... ..         | .016             | .009                  | .002            | .009             | .011           |
| Sodium " ... ..            | ...              | ...                   | ...             | ...              | .019           |
| Calcium sulphate ... ..    | ...              | ...                   | ...             | ...              | ...            |
| Magnesium " ... ..         | .087             | .001                  | .029            | .013             | ...            |
| Sodium " ... ..            | .080             | .084                  | .148            | ...              | .0-0           |
| Sodium nitrate " ... ..    | .013             | ...                   | ...             | ...              | ...            |
| Calcium chloride ... ..    | ...              | ...                   | ...             | ...              | ...            |
| Magnesium chloride ... ..  | ...              | ...                   | ...             | .005             | ...            |
| Sodium " ... ..            | .284             | .084                  | .018            | .080             | .036           |
| Iron oxide and alumina ... | .084             | .007                  | .013            | .004             | .008           |
| Silica ... ..              | .006             | .006                  | .023            | .011             | .036           |
| Total ... ..               | .424             | .140                  | .256            | .100             | .132           |
| Nature of soil ... ..      | Light brown clay | Buff, very sandy clay | Dark brown clay | Brown sandy clay | Red sandy clay |

| Laboratory No. ... ..      | 1922.    | 1923.      | 1909.                    | 1910.                  | 1921             |
|----------------------------|----------|------------|--------------------------|------------------------|------------------|
| Locality, miles and chains | 320-40   | 323-00     | 324-60                   | 322-10                 | 335-30           |
| Condition of pipe ... ..   | Bad      | Bad        | Bad                      | Good                   | Very bad         |
| Calcium carbonate ... ..   | .018     | .021       | .002                     | .025                   | .016             |
| Magnesium carbonate ... .. | .014     | .008       | .024                     | .009                   | .005             |
| Sodium " ... ..            | .046     | ...        | ...                      | ...                    | ...              |
| Calcium sulphate ... ..    | ...      | ...        | ...                      | ...                    | ...              |
| Magnesium sulphate ... ..  | ...      | .019       | .008                     | .084                   | .013             |
| Sodium " ... ..            | .015     | .008       | .005                     | .045                   | .027             |
| Sodium nitrate " ... ..    | ...      | Trace      | .008                     | .013                   | ...              |
| Calcium chloride ... ..    | ...      | ...        | ...                      | ...                    | ...              |
| Magnesium chloride ... ..  | ...      | ...        | ...                      | ...                    | ...              |
| Sodium " ... ..            | .036     | .303       | .063                     | .203                   | .018             |
| Iron oxide and alumina ... | .014     | .006       | ...                      | ...                    | .001             |
| Silica ... ..              | .016     | .006       | .018                     | .032                   | .011             |
| Total ... ..               | .159     | .370       | .125                     | .261                   | .091             |
| Nature of soil ... ..      | Red clay | Brown clay | Brownish grey sandy clay | Brown, very sandy clay | Brown sandy clay |

| Laboratory No. ... ..         | 1925.          | 1926.          | 1956.            | 1957.          | 1958.          |
|-------------------------------|----------------|----------------|------------------|----------------|----------------|
| Locality, miles and chains    | 336.18         | 336.38         | 340.50           | 353.77         | 354.21         |
| Condition of pipe ... ..      | Very bad       | Very bad       | Very bad         | Fair           | Fair           |
| Calcium carbonate ... ..      | .008           | .023           | .009             | .019           | .039           |
| Magnesium carbonate ... ..    | ...            | ...            | .005             | .016           | ...            |
| Sodium ... ..                 | ...            | ...            | .011             | .019           | ...            |
| Calcium sulphate ... ..       | .018           | .088           | ...              | ...            | .073           |
| Magnesium sulphate ... ..     | .031           | .057           | ...              | ...            | .050           |
| Sodium ... ..                 | ...            | .011           | .034             | .105           | .108           |
| Sodium nitrate ... ..         | ...            | ...            | ...              | ...            | ...            |
| Calcium chloride ... ..       | ...            | ...            | ...              | ...            | ...            |
| Magnesium chloride ... ..     | .003           | ...            | ...              | ...            | ...            |
| Sodium ... ..                 | .032           | .028           | .036             | .089           | .053           |
| Iron oxide and alumina ... .. | .004           | .004           | .016             | .015           | .008           |
| Silica ... ..                 | .005           | .007           | .008             | .011           | .005           |
| Total ... ..                  | .128           | .235           | .119             | .274           | .331           |
| Nature of soil ... ..         | Red sandy clay | Red sandy clay | Brown sandy clay | Red sandy clay | Red sandy clay |

| Laboratory No. ... ..         | 1959.    | 1960.    | 1961.    | 1962.      | 1963.      |
|-------------------------------|----------|----------|----------|------------|------------|
| Locality, miles and chains    | 357.43   | 376.40   | 379.42   | 382.63     | 385.03     |
| Condition of pipe ... ..      | Bad      | Bad      | Bad      | Good       | Fair       |
| Calcium carbonate ... ..      | .023     | .016     | .017     | .014       | .023       |
| Magnesium carbonate ... ..    | ...      | .011     | ...      | .012       | .014       |
| Sodium ... ..                 | ...      | .026     | ...      | .029       | .008       |
| Calcium sulphate ... ..       | .274     | ...      | .189     | ...        | ...        |
| Magnesium sulphate ... ..     | .120     | ...      | .171     | ...        | ...        |
| Sodium ... ..                 | .278     | .054     | .482     | .027       | .037       |
| Sodium nitrate ... ..         | ...      | ...      | .004     | ...        | ...        |
| Calcium chloride ... ..       | ...      | ...      | ...      | ...        | ...        |
| Magnesium chloride ... ..     | ...      | ...      | ...      | ...        | ...        |
| Sodium ... ..                 | .102     | .035     | .506     | .027       | .146       |
| Iron oxide and alumina ... .. | .008     | .001     | .003     | .002       | .008       |
| Silica ... ..                 | .001     | .005     | .005     | .013       | .010       |
| Total ... ..                  | .799     | .150     | 1.377    | .124       | .246       |
| Nature of soil ... ..         | Red clay | Red clay | Red clay | Brown clay | Brown clay |

This table shows that the whole of the soils examined contained soluble salts, varying in amount from one-tenth to one and a-third per cent. Corrosion more or less intense is therefore to be expected at all the points from which the samples were taken. This corrosion will be entirely prevented by the asphaltic covering where intact, but wherever it is chipped or scratched the pipe will be open to attack. This attack will be dependent upon—

(1.) The frequency with which the soil is wetted by rain or leakage.

(2.) The extent to which the soil retains moisture after rainfall owing to its topographical position or its physical struc-

ture. Clay pans and flats will be moist long after the ridges have dried and stiff clay will retain moisture for weeks after loose sand has lost all such through evaporation.

(3.) The quantity and nature of soluble salts in the soil. Within the limits shown by the analyses the effect will, as a rule, be greater where the total amount of salts is greater, but will be dependent still more upon whether or not those salts are derived from acids which have a strong affinity to iron. Chlorides, sulphates, and nitrates may be expected to have the worst effect.

Finally localisation of attack will result from localisation of exposed surfaces or of salts or moisture in the soil, and from lack of homogeneity of the steel.

*Prevention of Corrosion.*—Having thus arrived at a definite conclusion with regard to the causes of corrosion, it is a comparatively simple matter to suggest means of prevention, though the relative expense and adaptability of these means are matters for the consideration of the engineer in charge.

In short, what must be avoided is to allow moist soil to remain in contact with the bare metal of the pipes for any appreciable part of the year, especially where the ground is salty. This object is to be attained by—

- (1.) Continually renewing the coating of the pipes, so as to preserve it practically intact.
- (2.) Reducing leakage to a minimum.
- (3.) Diverting all surface water from the pipe line.
- (4.) Assisting the soil to dry up rapidly after rainfall.

This latter point is the only one which needs elucidation. The air of the interior is so dry at all seasons of the year and at times so hot, whilst the rainfall is so slight, that loose sandy soil will dry naturally too quickly to allow of extensive corrosion taking place. Stiff clay soils are however so retentive of moisture that where the soil is of this nature extra supervision of the pipes should be maintained with a view to keeping the coating intact, whilst the covering of soil should be reduced to a minimum, or even done away with, and any steps, locally applicable, taken to facilitate the draining and drying of the soil in the immediate vicinity of the pipes.

Renewals of the pipes will have to be undertaken as time goes on, and before such are made it would be well to have a thorough investigation made into the question of the suitability of mild steel for such work in the salty soils of the interior. Reasons, both practical and theoretical, point to its being far from an ideal material for such work.

In conclusion, I must acknowledge my indebtedness to Dr. F. S. Earp in the preparation of this report, that gentleman having made most of the necessary estimations and analyses.

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(b.) SECOND AND FINAL REPORT.

Since the presentation of my preliminary Report upon the corrosion of the G.W.S. pipes, the work of Dr. Earp and myself has been chiefly upon the completion of the analyses of soils from various parts of the pipe-line, upon determining the relative effect of these soils upon different brands of metal and upon experimenting with various substances likely to neutralise or retard the evil effect of the soils.

*Analyses of Soils.*—The accompanying Table 1 gives the analyses of 29 more soils from the pipe-track.

The variable action of these soils is dependent upon several independent factors, viz.:—

- (a.) The state of the pipe coating.
- (b.) The percentage of salts in the soil.
- (c.) The capacity of the soil for retaining moisture.
- (d.) The drainage of the soil.

The\*irregular pitting of the pipes has been imitated in the laboratory, and would also appear to be due to several causes, viz., irregular exposure of the pipe, lack of homogeneity of the metal, and water-line action.

TABLE 1.

| Laboratory No. ... ..         | 2057.                 | 2058.                           | 2059.                 | 2060.                     | 2061.            |
|-------------------------------|-----------------------|---------------------------------|-----------------------|---------------------------|------------------|
| Locality, miles and chains    | 2-52 from Weir.       | 4-61, Clackline.                | 4-62, Clackline.      | 4-72, Clackline.          | 6-36, Clackline. |
| Condition of Pipe ... ..      | Bad.                  | Bad.                            | Very bad.             | Bad.                      | Fair.            |
| Calcium carbonate ... ..      | ·015                  | ·008                            | ·007                  | ·005                      | ·008             |
| Magnesium „ ... ..            | ...                   | ·009                            | ·002                  | ·004                      | ...              |
| Sodium „ ... ..               | ...                   | ·055                            | ...                   | ...                       | ...              |
| Calcium sulphate ... ..       | ·005                  | ...                             | ...                   | ...                       | ·008             |
| Magnesium sulphate ... ..     | ·018                  | ...                             | ·008                  | ·004                      | ·087             |
| Sodium „ ... ..               | ·023                  | ·011                            | ·063                  | ...                       | ...              |
| Sodium nitrate ... ..         | ...                   | ...                             | ...                   | ...                       | ·001             |
| Calcium chloride ... ..       | ...                   | ...                             | ...                   | ...                       | ...              |
| Magnesium chloride ... ..     | ...                   | ...                             | ...                   | ·007                      | ·008             |
| Sodium chloride ... ..        | ·015                  | ·020                            | ·100                  | ...                       | ·469             |
| Iron Oxide and Alumina ... .. | ·001                  | ·006                            | ·015                  | ·006                      | ·008             |
| Silica ... ..                 | ·018                  | ·083                            | ·008                  | ·011                      | ·015             |
| Total ... ..                  | ·096                  | ·125                            | ·068                  | ·087                      | ·544             |
| Nature of soil ... ..         | Dark grey sandy clay. | Greenish mica with clay & sand. | Dark grey sandy clay. | Dark brown clay and sand. | Grey sandy clay. |

| Laboratory No. ... ..         | 2095.                     | 2157.                              | 2128.                   | 2129.                             | 2130.               |
|-------------------------------|---------------------------|------------------------------------|-------------------------|-----------------------------------|---------------------|
| Locality, miles and chains    | 19° 00<br>Werribee.       | Bed, North<br>side, Avon<br>River. | Northam<br>office yard. | Seabrook<br>Rail Mills,<br>88° 0. | Mendar,<br>92° 00.  |
| Condition of Pipe ... ..      | Bad.                      | Good.                              | Bad.                    | Fair.                             | Good.               |
| Calcium carbonate ... ..      | ·006                      | ·005                               | ·008                    | ·009                              | ·009                |
| Magnesium carbonate ... ..    | ·005                      | ·001                               | ·014                    | ·012                              | ·013                |
| Sodium ... ..                 | ...                       | ...                                | ·012                    | ·067                              | ·018                |
| Calcium sulphate ... ..       | ...                       | ...                                | ...                     | ...                               | ...                 |
| Magnesium sulphate ... ..     | ·010                      | ·013                               | ...                     | ...                               | ...                 |
| Sodium sulphate ... ..        | ...                       | ·003                               | ·014                    | ·010                              | ·016                |
| Sodium nitrate ... ..         | ...                       | ...                                | minute<br>trace.        | minute<br>trace.                  | minute<br>trace.    |
| Calcium chloride ... ..       | ...                       | ...                                | ...                     | ...                               | ...                 |
| Magnesium chloride ... ..     | ·001                      | ...                                | ...                     | ...                               | ...                 |
| Sodium ... ..                 | ·017                      | ·016                               | ·036                    | ·052                              | ·042                |
| Iron Oxide and Alumina ... .. | ·080                      | ·005                               | ·004                    | ·009                              | ·008                |
| Silica ... ..                 | ·075                      | ·012                               | ·016                    | ·019                              | ·014                |
| Total ... ..                  | ·134                      | ·055                               | ·104                    | ·163                              | ·118                |
| Nature of soil ... ..         | Brown grey<br>sandy clay. | Light<br>brown<br>sandy clay.      | Grey clay.              | Light<br>brown clay.              | Grey<br>sandy clay. |

| Laboratory No. ... ..         | 2121.                  | 2151.                      | 2152.                      | 2153.              | 2154.                |
|-------------------------------|------------------------|----------------------------|----------------------------|--------------------|----------------------|
| Locality, miles, and chains   | Mackering,<br>100° 00. | Wyola,<br>122° 03.         | Wyola,<br>122° 71.         | Wyola,<br>123° 57. | Wyola,<br>124° 40.   |
| Condition of pipe ... ..      | Fair.                  | Good.                      | Fair.                      | Fair.              | Fair.                |
| Calcium carbonate ... ..      | ·007                   | ·017                       | ·007                       | ·007               | ·011                 |
| Magnesium carbonate ... ..    | ·012                   | ...                        | ·005                       | ...                | ...                  |
| Sodium ... ..                 | ·010                   | ...                        | ...                        | ...                | ...                  |
| Calcium sulphate ... ..       | ...                    | ·008                       | ...                        | ·080               | ·009                 |
| Magnesium sulphate ... ..     | ...                    | ·053                       | ·006                       | ·245               | ·008                 |
| Sodium ... ..                 | ·017                   | ·084                       | ...                        | ...                | ...                  |
| Sodium nitrate ... ..         | ...                    | ...                        | ...                        | ·001               | minute<br>trace      |
| Calcium chloride ... ..       | ...                    | ...                        | ...                        | ...                | ...                  |
| Magnesium chloride ... ..     | ...                    | ...                        | ·002                       | ·055               | ·004                 |
| Sodium ... ..                 | ·088                   | ·415                       | ·029                       | 3° 050             | ·319                 |
| Iron oxide and alumina ... .. | ·005                   | ·012                       | ·010                       | ·156               | ·014                 |
| Silica ... ..                 | ·081                   | ·984                       | ·180                       | ·037               | ·044                 |
| Total ... ..                  | ·110                   | ·608                       | ·219                       | 3° 631             | ·409                 |
| Nature of soil ... ..         | Grey clay.             | Grey sand,<br>little clay. | Grey sand,<br>little clay. | Grey sand.         | Buff clayey<br>sand. |

| Laboratory No. ... ..           | 2121.                | 2122.                 | 2123.                 | 2124.                | 2125.                 |
|---------------------------------|----------------------|-----------------------|-----------------------|----------------------|-----------------------|
| Locality, miles, and chains     | Wyola,<br>124° 00.   | Bungalla,<br>126° 11. | Bungalla,<br>126° 00. | Bungalla,<br>127° 3. | Bungalla,<br>140° 23. |
| Condition of pipe ... ..        | Very bad.            | Good.                 | Fair.                 | Very bad.            | Very bad.             |
| Calcium carbonate ... ..        | ·008                 | ·004                  | ·011                  | ·006                 | ·009                  |
| Magnesium carbonate ... ..      | ...                  | ...                   | ·014                  | ·013                 | ·013                  |
| Sodium ... ..                   | ...                  | ...                   | ·027                  | ·012                 | ...                   |
| Calcium sulphate ... ..         | ·001                 | ·018                  | ...                   | ...                  | ...                   |
| Magnesium sulphate ... ..       | ·019                 | ...                   | ...                   | ...                  | ·006                  |
| Sodium ... ..                   | ...                  | ...                   | ·020                  | ·026                 | ·015                  |
| Sodium nitrate ... ..           | ...                  | ...                   | ...                   | ...                  | ...                   |
| Calcium chloride ... ..         | ...                  | ·006                  | ...                   | ...                  | ...                   |
| Magnesium chloride ... ..       | ...                  | ·012                  | ...                   | ...                  | ...                   |
| Sodium ... ..                   | ·122                 | ·001                  | ·068                  | ·067                 | ·060                  |
| Iron, oxide, and alumina ... .. | ·016                 | ·006                  | ·042                  | ·028                 | ·017                  |
| Silica ... ..                   | ·089                 | ·051                  | ·266                  | ·183                 | ·156                  |
| Total ... ..                    | ·285                 | ·078                  | ·438                  | ·305                 | ·296                  |
| Nature of soil ... ..           | Grey clayey<br>sand. | Pink sandy<br>clay.   | Grey sandy<br>clay.   | Grey clayey<br>sand. | White<br>sandy clay.  |

| Laboratory No. ... ..       | 2196                 | 2197                          | 2340                            | 2341                        | 2342                        |
|-----------------------------|----------------------|-------------------------------|---------------------------------|-----------------------------|-----------------------------|
| Locality, miles, and chains | Bungalla,<br>141.70. | Keller-<br>berrin,<br>148.75. | Keller-<br>berrin,<br>152.40.   | Doodle-<br>kine,<br>154.40. | Doodle-<br>kine,<br>155.33. |
| Condition of pipe ... ..    | Bad.                 | Good.                         | Bad.                            | Fair.                       | Bad.                        |
| Calcium carbonate...        | .011                 | .011                          | .008                            | .028                        | .017                        |
| Magnesium carbonate ...     | .012                 | .011                          | .008                            | ...                         | .017                        |
| Sodium ..                   | .027                 | .043                          | .061                            | ...                         | .012                        |
| Calcium sulphate ...        | ...                  | ...                           | ...                             | ...                         | ...                         |
| Magnesium sulphate ...      | ...                  | ...                           | ...                             | .021                        | ...                         |
| Sodium sulphate ...         | .046                 | .012                          | .034                            | ...                         | .028                        |
| Sodium nitrate ...          | ...                  | ...                           | .028                            | .019                        | .007                        |
| Calcium chloride ...        | ...                  | ...                           | ...                             | ...                         | ...                         |
| Magnesium chloride ...      | ...                  | ...                           | ...                             | ...                         | ...                         |
| Sodium ..                   | .222                 | .040                          | .053                            | .142                        | .102                        |
| Iron oxide and alumina ...  | .002                 | .022                          | .031                            | .007                        | .015                        |
| Silica ... ..               | .096                 | .118                          | .090                            | .021                        | .063                        |
| Total ... ..                | .356                 | .258                          | .315                            | .238                        | .261                        |
| Nature of soil ... ..       | Grey clayey<br>sand. | Grey clayey<br>sand.          | Brownish<br>grey sandy<br>clay. | Buff sandy<br>clay.         | Grey clay.                  |

| Laboratory No. ... ..           | 2343                    | 2344                                           | 2017                                 | 2330                                    |
|---------------------------------|-------------------------|------------------------------------------------|--------------------------------------|-----------------------------------------|
| Locality, miles, and chains ... | Hine's Hill,<br>167.58. | 373.7 Soil in<br>contact with<br>incrustation. | 326 Soil in<br>contact with<br>2016. | 361.70 Soil in<br>contact with<br>2017. |
| Condition of pipe... ..         | Very bad.               | Bad ?                                          | Bad ?                                | Bad ?                                   |
| Calcium carbonate ... ..        | .029                    | .016                                           | .017                                 | .024                                    |
| Magnesium carbonate ... ..      | .015                    | .016                                           | ...                                  | ...                                     |
| Sodium ..                       | ...                     | ...                                            | ...                                  | .027                                    |
| Calcium sulphate ... ..         | ...                     | ...                                            | .083                                 | ...                                     |
| Magnesium sulphate ... ..       | .017                    | .003                                           | ...                                  | .070                                    |
| Sodium ..                       | .138                    | .092                                           | ...                                  | .561                                    |
| Sodium nitrate ... ..           | .039                    | ...                                            | ...                                  | ...                                     |
| Calcium chloride ... ..         | ...                     | ...                                            | .012                                 | ...                                     |
| Magnesium chloride ... ..       | ...                     | ...                                            | .051                                 | ...                                     |
| Sodium ..                       | .356                    | .083                                           | .126                                 | .222                                    |
| Iron oxide and alumina ...      | .013                    | .009                                           | .020                                 | .014                                    |
| Silica ... ..                   | .018                    | .008                                           | .013                                 | .018                                    |
| Total... ..                     | .625                    | .227                                           | .272                                 | .266                                    |
| Nature of soil ... ..           | Buff sandy<br>clay.     | Bright red<br>clay.                            | Buff clay.                           | Brownish<br>red clay.                   |

*Composition of External Incrustation.*—A typical sample of incrustation from the pipe in contact with soil No. 2284 of Table 1 was analysed with the following results :—

|                                               | per cent. |
|-----------------------------------------------|-----------|
| Iron peroxide, $\text{Fe}_2\text{O}_3$ ... .. | 86.96     |
| Iron protoxide, $\text{FeO}$ ... ..           | 6.44      |
| Lime, $\text{CaO}$ ... ..                     | 1.08      |
| Magnesia, $\text{MgO}$ ... ..                 | .81       |
| Water below $100^\circ$ ... ..                | 4.06      |
| Water above $100^\circ$ ... ..                | 1.74      |
| Carbonic anhydride, $\text{CO}_2$ ... ..      | 3.68      |
| Sulphuric anhydride, $\text{SO}_3$ ... ..     | .24       |
| Chlorine, $\text{Cl}$ ... ..                  | .43       |
| Insoluble clay, etc. ... ..                   | 43.80     |

99.23

This is typical rust admixed with a good deal of soil. The presence of carbonates, sulphates, and chlorides shown by the analysis points to the influence of soluble salts in the formation of the incrustation.

Several other similar samples were examined and found to be identical with that analysed.

A qualitative analysis was also made of a sample of internal incrustation. This was of similar character, principally hydrated peroxide of iron with a little protoxide, carbonic acid, and mechanically held sand and organic matter.

*Relative Corrosion of Iron and Steel.*—Experiments have been made to determine the relative effect of the soils upon iron and steel, the idea being to determine, if possible, whether the steel at present in use was less suited for the purpose than iron or other steels. The metals tested were (1), Steel from present pipes ; (2), Mannesmann steel ; (3), soft iron. Bars of these metals were immersed in water extracts of the soils to such a depth that the area of metal exposed to the action of water was constant, viz., 27 sq. centimetres (4 3-16 sq. inches). Corrosion was apparent within a few hours after immersion, and after four days the amount of metallic iron removed from the bars in the form of rust was determined with the results in Table 2.

TABLE 2.

| Extract from Soil No.          | Pipe steel.                        | Mannesmann steel. | Iron. |
|--------------------------------|------------------------------------|-------------------|-------|
|                                | Milligrammes removed by corrosion. |                   |       |
| 2182 ... ..                    | 11.3                               | 19.8              | 9.4   |
| 2195 ... ..                    | 16.9                               | 21.2              | 15.1  |
| 2196 ... ..                    | 23.5                               | 24.9              | 21.6  |
| 2241 ... ..                    | 17.4                               | 20.7              | 16.5  |
| 2243 ... ..                    | 15.0                               | 24.5              | Lost  |
| Mixed extracts of 10 soils ... | 10.5                               | 10.5              | 10.2  |

As was expected from its more homogeneous structure, the action on iron was slightly less throughout than that on either steel. However the inferior strength and increased cost probably more than counterbalances the slightly greater resistance to corrosion. Of the two steels experimented on, that in the present pipes is decidedly more resistant.

In connection with the corrosion of steel water pipes by salts in the soil, the following extract is of interest. It is taken from a Bulletin of the United States Geological Survey on reinforced concrete pipes.\*

Steel pipe is naturally limited to a thin shell on account of its great strength, weight, and cost. It is easily attacked by salts and acids, both on the inside by the water flowing through it and on the

\* Experiments on steel concrete pipes on a working scale by John Washington, 1905.



outside by the material surrounding it. A slight deterioration in so thin a shell means a large loss in strength, and the life of a steel pipe is therefore limited to a few years, depending upon the nature of the material in which it is laid. Experience has shown that in alkali ground in Southern California the life of a sheet-steel pipe is short. The life of the pipe may be lengthened by a coating, both inside and outside, of asphaltic material. The coating is applied by dipping the pipe into a hot bath of the asphalt mixture. If this dipping is not carefully done at just the proper temperature it is not likely to add much to the life of the pipe. The coating is liable to be broken in places by careless handling in transit from the factory to the work, and unless such places are recoated they are soon attacked, and the efficiency of the pipe is thus materially lessened. In all of the projects in the arid States more or less alkali ground is encountered, and in many of the projects provision has to be made for the drainage of the lands to get rid of the alkali. Under these circumstances other and more durable material than steel or iron must be sought.

*Prevention of Corrosion.*—Means were sought for preventing or at any rate checking the action of the salt of the soil on the pipe. Assuming, as stated in my previous report, that the cause of corrosion is the electrolysis of the dissolved salts with the consequent momentary liberation of substances of an acid character, reduction of corrosion should be brought about by the application to the soil, or to the surface of the pipe, of a substance which would either lower the conductivity of the salt solutions, or else immediately neutralise the liberated acid.

Substances of the former class appear mainly to be both expensive and difficult to apply practically. That they do materially reduce corrosion the following figures attest :—

|                      | Corrosion with<br>solution before<br>addition of<br>alcohol. | Corrosion after<br>addition of<br>alcohol. |
|----------------------|--------------------------------------------------------------|--------------------------------------------|
| Pipe steel ... ..    | 19.1                                                         | 8.9                                        |
| Mannesmann steel ... | 14.6                                                         | 7.0                                        |
| Iron ... ..          | 16.0                                                         | 9.4                                        |

Substances of the latter class must be alkaline, but not carbonated alkalis, these give rise to carbonic acid under the influence of electrolysis. Limestone was therefore expected to be valueless, and found by experiment to be so. Effective substances would be such oxides, hydrates, and basic silicates, as are readily attacked by acids. The following substances were actually tried and found effective :—

- (1.) Caustic soda.
- (2.) Caustic potash.
- (3.) Ammonia.
- (4.) Quick lime.
- (5.) Freshly slaked lime.
- (6.) Sodium silicate (water glass).

Portland cement was not tried, but would undoubtedly be equally effective.

The effect of all these substances was to indefinitely prevent corrosion, provided fresh supplies of air were not allowed to reach the soil solution with which the metal was in contact. Herein lies the bar to their practical application. Air contains sufficient carbonic acid to convert lime, etc., in process of time into the corresponding carbonates, and then all their protective influence is lost. The experiments with lime were therefore interesting, but disappointing. Two steel bars were partly immersed in 1 per cent. solution of sodium chloride and sodium sulphate. In one hour signs of corrosion were apparent, and rapidly increased. After two days, the iron removed by corrosion was 26.3 and 22.3 milligrams respectively. The corrosion was general, but slightly more marked near the surface of the solution. The experiment was then repeated with solutions of the same salts containing in addition  $\frac{1}{8}$  per cent. of lime. For four days no action whatever was noticeable, after that a very slow corrosion set in at the water line only, where the solution had become saturated with atmospheric carbonic acid. The action was allowed to proceed for 70 days, with the following results :—

The corrosion was confined to the surface level of the liquid.

The steel was corroded to a maximum depth of  $1\frac{1}{2}$  millimetres at this point.

The rust formed nodular incrustations, portions of which dropped off from time to time.

The rates of corrosion were 2.5 and 2.9 milligrams per day, as against 13.1 and 11.1 when no lime was used.

A similar experiment was made with the water extract of soil No. 2284, with the following results :—

|                        | Corrosion after six days. |            |
|------------------------|---------------------------|------------|
|                        | Without lime.             | With lime. |
| Pipe steel ... ..      | 35.7                      | 6.1        |
| Mannesmann steel ... . | 38.1                      | 10.3       |
| Iron ... ..            | 44.2                      | 3.8        |

The deductions to be drawn are that a thin layer of lime between the pipes and the soil would considerably retard corrosion at first, but that by absorption of carbonic acid from the air the protective effect would be gradually lessened until it became nil at the end of a very few years at most.

What may be called chemical methods of checking corrosion do not therefore appear to be practically successful. One is obliged

to fall back on the purely mechanical one of keeping the pipes sheltered from action by a strongly and closely adherent and impervious coating of some material having itself no effect upon the steel.

I have been unable to obtain details of the Barff process of treating pipes. It consists, I believe, of heating them in an atmosphere of steam until a thick and very adherent coating of magnetic oxide forms on the surface. This coating is said to be an excellent protection against rusting.

Time and experience have led to an almost universal belief in the tar-asphalt coating. It was lately stated in a technical journal that unless the carbolic acid be previously removed from the coal tar, such a coating has itself an action on the pipe, and tends to increase the loosening and flaking off which is the main objection to this coating. This is a point which should be noted if local tar is used. Mr. Reynoldson's own suggestion to use a jute binding with the tar-asphalt coat appears to be an excellent one. To avoid destruction in the hot asphaltic mixture the jute may require a previous soaking in a heavy oil, such as crude vaseline. Experiments on a working scale with this jute covering would be well justified, and at the same time as an alternative the toughening effect of the addition to the asphalt mixture of 10 or 15 per cent. of flake mica.

Graphite paint is largely used in the United States for the protection of metal work above ground with what are said to be excellent results. This, too, should be worth a working trial.

*Final Conclusions.*—The results of all the experiments made by myself, as well as the accounts of others made elsewhere, confirm me in the following opinions :—

1. Steel corrodes slowly when kept quite dry.
2. Steel rusts comparatively rapidly in contact with air and water.
3. The life of steel pipes is very considerably shortened when the soil in which they are laid contains over 0.1 per cent. of soluble salts, such as common salt, gypsum (calcium sulphate), etc.
4. They can only be preserved by a perfectly adherent and impermeable coating which itself has no action on the metal.
5. Such a perfect coating, owing to necessary rough handling, being impossible of attainment, the nearest possible approach to it should be secured.
6. In view of the necessary imperfections of the coating, the strongest efforts should be made to keep the soil in contact with pipes absolutely dry by drainage, diversion of surface water, checking leaks, substituting sand for clay as a covering, etc.

7. Iron is somewhat more resistant to corrosion than steel, and occasionally it may be more economical to use it in place of steel for pipes. In each case the relations between costs and efficiency must be carefully worked out.

EDWARD S. SIMPSON, B.E., F.C.S.,  
Mineralogist and Assayer.

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*Note.*—Researches into the causes of the corrosion of the pipes on the Goldfields Water Supply main were made in the Survey Laboratory during the year 1906. To assist in these investigations it was found necessary to enlist the services of Dr. F. S. Earp for a period of six months ; his salary, however, was paid by the Goldfields Water Supply Administration, in whose interest the special work was carried out. The information obtained as a result of the laboratory investigations of the soils from the Goldfields Water Supply pipe track, and their effect upon pipe steel and iron, are of considerable interest, and of more than mere local importance.

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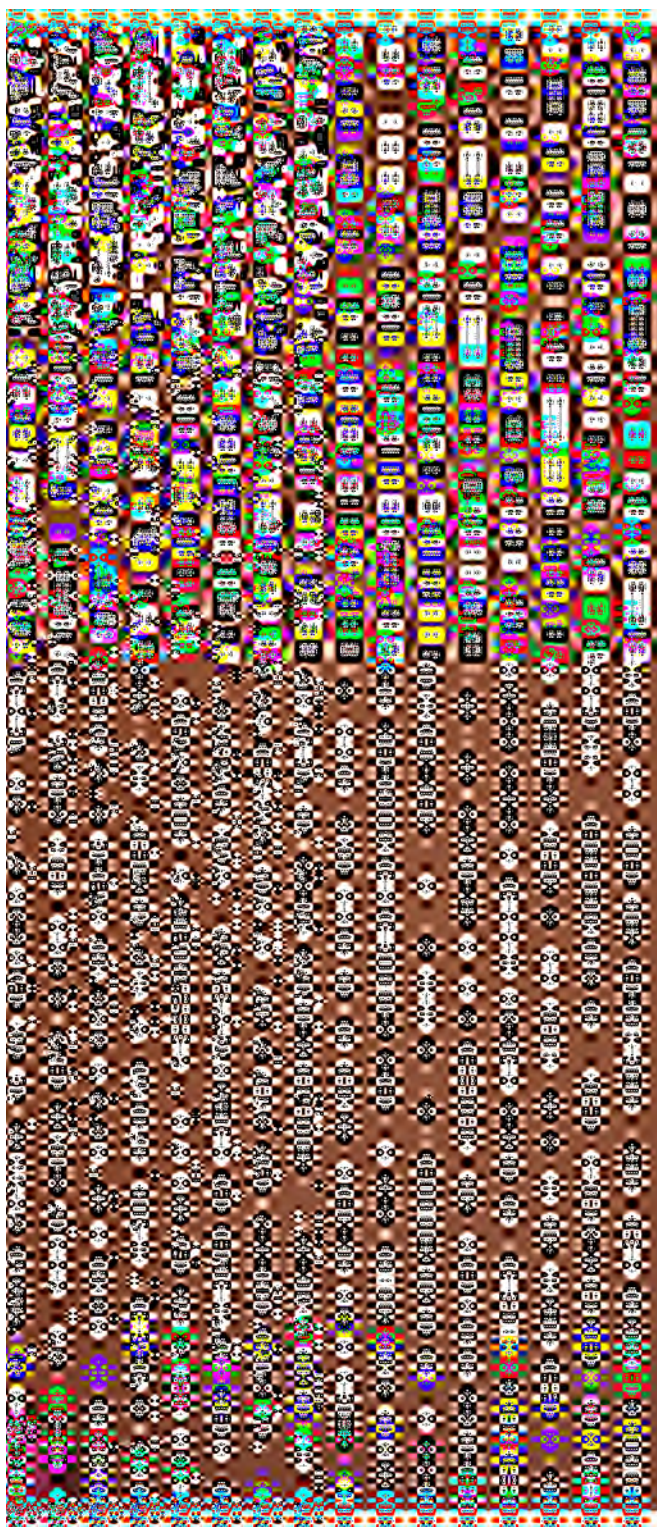
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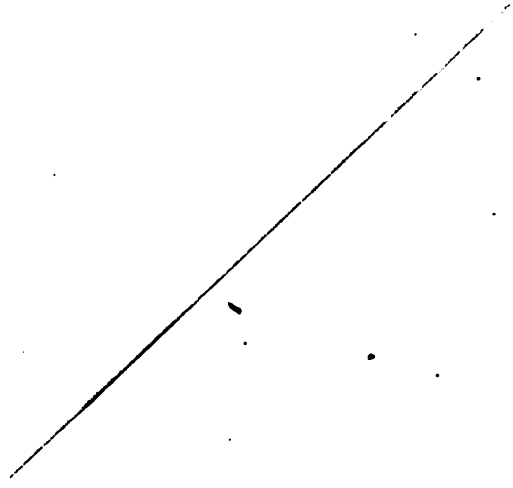
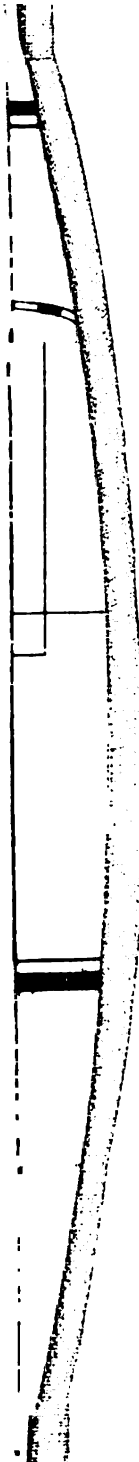




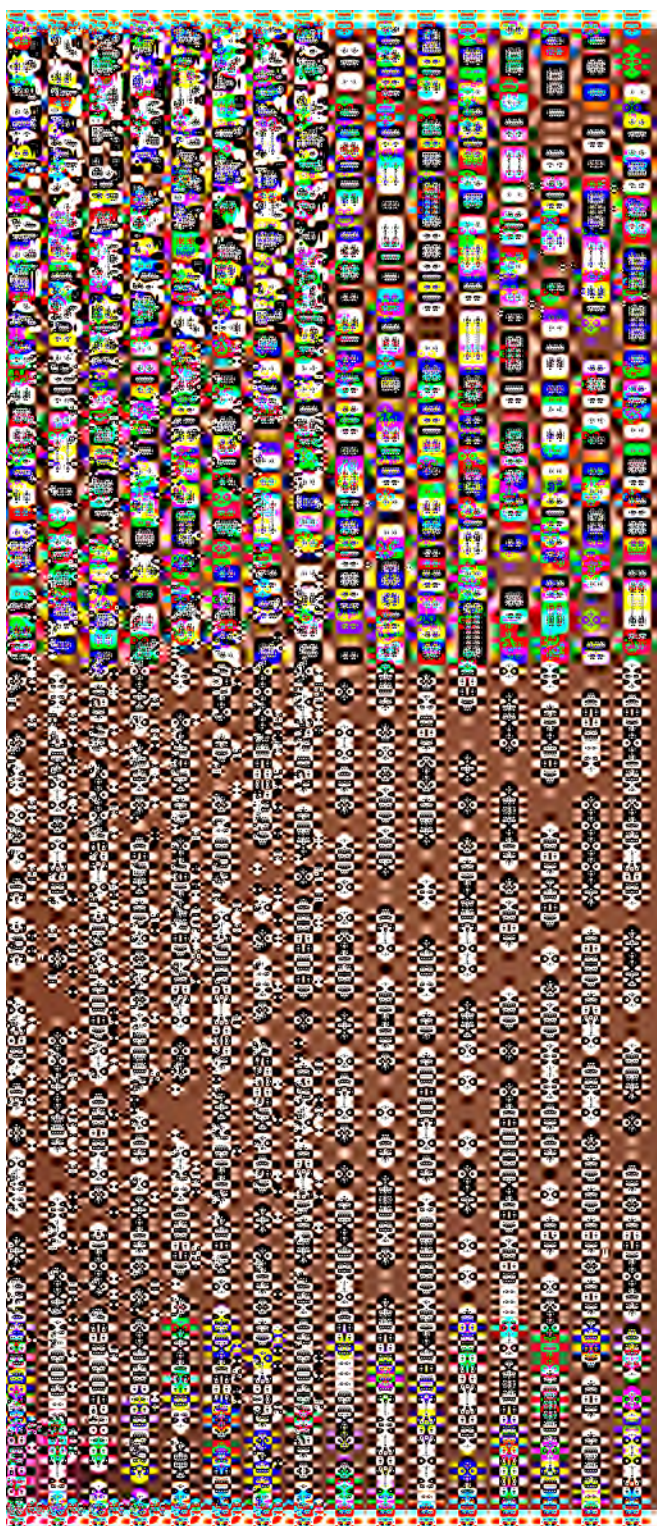
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